U.S. Department
of Transportation

**Federal Highway
Administration**

400 Seventh St., S.W.
Washington, D.C. 20590

JUL 2 6 1999

Reply to: HMCS-30

Dear Report Recipient,

Enclosed is the Federal Highway Administration (FHWA), Office of Motor Carrier and Highway Safety (OMCHS), report titled "Research Design: Validation of Simulation Technology in the Training, Testing and Licensing of Tractor-Trailer Drivers, Final Report" (Publication Number FHWA-MC-99-060).

This report, prepared by Science Application International Corporation in association with George Mason University, describes the peer-reviewed research design to be employed in the planned OMCHS simulator validation study to empirically assess the benefits of the technology. This report also addresses the relevant literature and provides the simulation-based driving scenarios and other supporting materials.

FHWA's first report on the subject of truck simulators ("Commercial Motor Vehicle Simulation Technology to Improve Driver Training, Testing and Licensing Methods," April 1996, (NTIS Publication Number PB96-183405, telephone 1-800-553-6847 or 703-605-6000) evaluated the performance of the truck simulators available at that time. The research indicated that low-to-mid-cost truck simulators had "come of age" and recommended the Digitran SafeDrive 1000 as the testbed for validation study.

Since the 1996 report, the cost of simulation technology has decreased while the functionality has increased. As such, OMCHS is in the process of conducting a reassessment of the marketplace in order to assure the simulator selected for the study is the one that best meets our needs. The Veridan organization (Calspan, Buffalo, NY) is conducting the market research and will recommend a simulator for use in the follow-on validation study. The reassessment is scheduled for completion in the first quarter of 2000.

Additional copies of the research design report are available by writing or faxing your request, which specifies the publication number and quantity desired, to:

U.S. Department of Transportation
Subsequent Distribution Office (SVC-121.23)
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3341-Q 75th Avenue
Landover, MD 20785

FAX: 301-386-5394 Help Line: 301-322-4961

Individuals with Internet access can obtain an electronic version of the research design report by accessing the Department of Transportation Information Services Web site at http://isweb.tasc.dot.gov under "On-Line D.O.T. Publications" and searching on FHWA-MC-99-060.

Further questions or comments can be directed to the OMCHS Simulator Program Manager, Mr. Jerry Robin, at (202) 366-2985 or Mr. Ron Finn at (202) 366-0647.

Sincerely yours,

Julie Anna Cirillo
Program Manager, Motor Carrier
and Highway Safety

Enclosure

U.S. Department of Transportation
Federal Highway Administration

RESEARCH DESIGN: VALIDATION OF SIMULATION TECHNOLOGY IN THE TRAINING, TESTING, AND LICENSING OF TRACTOR-TRAILER DRIVERS

FINAL REPORT

Publication No. FHWA-MC-99-060

May, 1999

FOREWORD

This report documents the first phase of a two-phase effort for the validation of simulation technology in the training, testing, and licensing of tractor-trailer drivers. Specifically, this report describes the research design, Phase 1, necessary to implement an empirical investigation to be conducted in Phase 2. The research design presented in this report is intended to provide basic guidance in the conduct of Phase 2. It is a general framework for conducting the validation, but it provides for flexibility in design revisions as the project develops.

This report briefly discusses the relevant literature, fact-finding, and industry interests. It also provides peer-reviewed, simulation-based driving scenarios with supporting materials. The main portion of the report is the research methodology and includes the procedures and data analysis for the conduct of Phase 2.

This report will provide some insight into the process being considered for the Phase 2 validation effort. The Office of Motor Carrier and Highway Safety (OMCHS) anticipates a 1999 (calendar year) start for the conduct of Phase 2. The focus in 1999 will be the market reassessment as described herein.

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-MC-99-060		

4. Title and Subtitle Research Design: Validation of Simulation Technology in the Training, Testing, and Licensing of Tractor-Trailer Drivers -- Final Report	5. Report Date 6. Performing Organization Code
7. Author(s) Dr. Cathy Emery, Jerry Robin, Ronald Knipling, Ron Finn, Stephen Fleger	8. Performing Organization Report No. FHWA-MC-99-060
9. Performing Organization Name and Address Science Applications International Corporation Turner-Fairbank Highway Research Center 6300 Georgetown Pike McLean, VA 22101	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Federal Highway Administration Office of Motor Carrier and Highway Safety 400 7th Street SW Washington, DC 20590	13. Type of Report and Period Covered FHWA Technical Report 14. Sponsoring Agency Code

15. Supplementary Notes

This research was conducted by Science Applications International Corporation and George Mason University. It was administered through the Turner-Fairbank Highway Research Center. Jerry Robin and Ron Finn co-managed this research initiative for the Office of Motor Carrier and Highway Safety.

16. Abstract

The Federal Highway Administration (FHWA), Office of Motor Carrier Highway Safety (OMCHS) is conducting research to validate the use of low-to mid-cost simulator for commercial driver training, testing and licensing. The primary purpose of the study is to examine how simulator technology, as compared to conventional methods, may facilitate and enhance tractor-trailer driver performance. This report details the proposed research design to conduct the empirical simulator validation study.

The research design consists of three distinct parts. Part 1 addresses the forward transfer of training for entry-level drivers. Part 2 is an assessment of the advanced capabilities of the test simulator. Part 3 is a longitudional study of the drivers that have successfully completed either the truck-based or simulator-based driver training program and have gone onto earn their Commercial Drivers License.

A previous OMCHS report titled, "Commercial Motor Vehicle Simulation Technology To Improve Driver Training, Testing and Licensing Methods Final Report - April 1996," evaluated truck driving simulators in the United States and Europe. The report indicated that truck driving simulation was sufficiently mature and recommended that FHWA validate this technology. The Digitran SafeDrive 1000 was recommended as the test bed for the follow-on validation study. A copy of the report can be obtained by contacting the National Technical Information Service (703-605-6000 or 1-800-553-6847) and referencing NTIS Publication Number PB96-183405,

The validation study will commence in FY 1999. It will start with a reassessment of the commercial marketplace to assure the simulator selected as the test bed for the study reflects the most up-to-date information and best meets the needs of OMCHS.

17. Key Words	18. Distribution Statement
Driving Simulator, Truck Driver Training, Heavy Trucks, Commercial Motor Vehicles, , Tractor-Trailers.	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

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EXECUTIVE SUMMARY

Simulators have been successfully employed within the military and commercial sectors for several decades. While the preponderance of simulation technology was developed to satisfy aviation training needs, similar technology has been applied to the training of skills in other contexts, such as petrochemical plants, nuclear power stations, locomotives, ships, and ground vehicles. Now, low-cost, full-mission, high-fidelity commercial motor vehicle (CMV) simulators are available in the commercial marketplace due to recent technological breakthroughs. These devices may be useful tools to supplement the training, testing, and licensing of CMV operators. However, there has been little systematic effort by either the private or public sector to validate the transferability of simulation training to real driving, or to assess the potential efficiency of simulation in driver training, testing and licensing.

Preliminary research conducted by FHWA and reported in *Commercial Motor Vehicle Simulation Technology to Improve Driver Training, Testing, and Licensing Methods: Final Report* (DOT Publication No. FHWA-MC-96-003, 1996)[1] evaluated the functional capabilities of low-cost truck driving simulators in the United States and Europe. On the basis of the report's assessment, the FHWA Office of Motor Carrier and Highway Safety (OMCHS) believes simulators hold considerable promise for improving truck driver proficiency, if their value can be sufficiently demonstrated. Thus, the OMCHS has implemented a simulation research program to assess the use of simulation for the training, testing, and licensing of tractor-trailer drivers. The OMCHS simulation research program consists of a validation project of a low- to mid-cost simulator for driver training, testing, and licensing. It also includes the participation in and integration of the National Advanced Driving Simulator (NADS), which is spearheaded by the National Highway Traffic Safety Administration (NHTSA).

This report will address the validation effort of the OMCHS simulator research program. The validation effort comprises two phases. The first phase, which is the focus of this report, is to develop the research design to validate the use of simulation technology for the training, testing, and licensing of CMV operators. The second phase is the empirical investigation using the Phase 1 research design. Phase 1 includes a review of the literature, proposed research design, the simulation-based driving scenarios, and the appendices. The driving scenarios and the research design have been previously submitted to extensive peer review through independent and interactive workshops. The peer review participants were selected on the basis of their expertise and working knowledge in the heavy vehicle industry. Their input is significantly represented in the overall research design and driving scenario content.

One objective of the validation effort is to determine if the use of simulator-supplemented training, compared with traditional behind-the-wheel (BTW) tractor-trailer training, results in the same, if not better, performance on the Commercial Drivers License (CDL) examination. To this

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[1] This publication is from the National Technical Information Service (NTIS) by calling either (800) 553-6847 or (703) 605-6000 and referencing NTIS Publication No. PB96-183405.

end, the research design seeks to compare driver skill acquisition in a simulator with driver performance behind the wheel of a tractor-trailer truck. This comparison will be addressed through an empirical investigation (Phase 2) that involves a forward transfer of training (Part 1) with student tractor-trailer drivers who will be trained on all units of the Professional Truck Drivers Institute of America (PTDIA[2]) curriculum. Students will be divided between two groups, with one group receiving conventional training and the other receiving simulation-supplemented training. Simulator assessment will be on 10 of the 16 units from the PTDI curriculum for Basic Operation and Safe Operating Practices portions. Because only 10 units have BTW training, these units will provide the data for comparison between the two groups. However, all students will receive full training on *all* units, but hands-on training under simulated conditions will be on only the ten BTW units identified in the table below. In January, 1999 new PTDI Tractor Trailer Curriculum Standards guidelines were unveiled although BTW hours remained unchanged at 44 hours. This report reflects the "old" standard, as revised by the peer review groups.

Behind-the-Wheel (BTW) Hours Allocation to Groups

		Conventional	Experimental	
a. Basic Operation		Truck Hrs	*Sim Hrs*	Truck Hrs
Unit				
1.4	Basic Control	2.25	1.50	.75
1.5	Shifting	.75	.50	.25
1.6	Backing	7.00	5.00	2.00
1.7	Coupling & Uncoupling	1.00	.75	.25
1.8	Proficiency Development	15.00	10.00[1 2]	5.00[1 2]
	Total	**26.00**	**17.75**	**8.25**
		Conventional	Experimental	
b. Safe Operating Practices		Truck Hrs	*Sim Hrs*	Truck Hrs
Unit				
2.1	Visual Search[1]	2.50	1.75	.75
2.2	Communication	1.00	.75	.25
2.4	Space Management	1.75	1.25	.50
2.5	Night Operation	2.25[2]	1.50[2]	.75[2]
2.7	Proficiency Development	10.50	7.00[1]	3.50[1]
	Total	**18.00**	**12.25**	**5.75**
	Grand Total	**44.00**	**30.00**	**14.00**

[1] Requires LOW- and HIGH-density traffic.
[2] Includes Range + Street BTW.

Driver performance will be assessed, and measures will include the number of trials necessary to achieve the skill-level objectives for each of the training lesson units, and the amount of time

[2] PTDIA has recently changed its name to the Professional Truck Driver Institute (PTDI) because the association now certifies schools in Canada and Mexico.

necessary to pass the skill unit. The criterion task for the transfer of training will be student driver's performance on the CDL. A second objective is to assess whether simulation might be used in the testing environment. Two in-course examinations, the Pre-Street Range Test (PSRT) and the Final Examination Road Test (FERT), based on the Model Curriculum will be administered as both a truck-based and a simulation-based test. These tests will provide for (1) an assessment of componential skill acquisition on a pass/fail basis and (2) a comparative assessment of skill acquisition in simulation.

Additionally, the validation effort seeks to determine the relationship between type of training method (i.e., simulation vs. truck) and actual job performance. A longitudinal study (Part 3) will be conducted to determine if simulator-based training ultimately results in reliable differences in driver's performance. The student driver's post-training driving record will be examined at three and 12 months following completion of the CDL. Measures of on-the-job driver performance during this part of the study will include the number of accidents, the number of citations, and supervisory ratings. The table on the next page illustrates Parts 1 and 3 of the research design. Because these two parts are interrelated, they are being depicted together, although they are not sequential events. Part 2, the advanced simulator capabilities assessment, follows Part 1 in time but is not contingent upon data gathered from it. Therefore, it is depicted in a subsequent, separate table.

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Truck Simulation Validation Research Design—Parts 1 & 3

		Part 1—Forward Transfer of Training (TOT)									Part 3—Longitudinal Component	
		Training/Testing Sequence									*Performance Sequence*	
Group	**% of BTW Allocation of Hours**	***Basic operation***	**Proficiency Development**	**PSRT**	**PSRT**	***Safe operating practices***	**Proficiency Development**	**FERT**	**FERT**	**CDL Test**	**Job Performance 3 Months**	**Job Performance 12 Months**
Conventional n = 24 (12 subjects in each subgroup)	100% Truck 0% Simulator (T = 44 hours) (S = 0 hours)	Units 1.4 -1.7	Unit 1.8	T	S	Units 2.1-2.6	Unit 2.7	T	S	T	✦Supervisory Ratings ✦Accidents ✦Citations ✦Driver Comments	✦Supervisory Ratings ✦Accidents ✦Citations ✦Driver Comments
				S	T			S	T			
Experimental n = 24 (12 subjects in each subgroup)	34% Truck 66% Simulator (T = 14 hours) (S = 30 hours)	Units 1.4 -1.7	Unit 1.8	T	S	Units 2.1-2.6	Unit 2.7	T	S	T	✦Supervisory Ratings ✦Accidents ✦Citations ✦Driver Comments	✦Supervisory Ratings ✦Accidents ✦Citations ✦Driver Comments
				S	T			S	T			

(Optional) Second Simulator Device

Experimental n = 24 (12 subjects in each subgroup)	34% Truck 66% Simulator (T = 14 hours) (S = 30 hours)	Units 1.4 -1.7	Unit 1.8	T	S	Units 2.1 -2.6	Unit 2.7	T	S	T	✦Supervisory Ratings ✦Accidents ✦Citations ✦Driver Comments	✦Supervisory Ratings ✦Accidents ✦Citations ✦Driver Comments
				S	T			S	T			

Note. BTW—Behind-the-Wheel; T—Truck-based test; S— Simulation-based test; PSRT—Pre-Street Range Test; FERT—Final Examination Road Test; and CDL—Commercial Drivers License. General Information: PTDI Curriculum = 147.5 training hours (103.5 class/lab + 44 hours BTW). PTDI has revised the curriculum requirments, but BTW hours remain unchanged. Performance Measures: Number of training trials for each training objective and amount of time to reach the training objective. The design allows for inter- and intra-group comparisons.

In Part 2, the advanced simulator capabilities assessment, experienced and novice truck drivers will execute simulated emergency and dangerous maneuvers, as well as simulated operation of doubles and triples for Unit 1.9, Special Rigs; Unit 2.3, Speed Management; Unit 2.6, Extreme Driving Conditions; and Unit 3.2, Emergency Maneuvers of the PTDI Tractor-Trailer Driver Curriculum. The objective of the advanced capabilities assessment is to "showcase" and assess the technology and determine the appropriateness of simulation for training, testing, and licensing tractor-trailer drivers on these particular maneuvers and vehicle configurations. The measures of performance will include objective and subjective data. Driver performance measures (e.g., lane deviation, braking performance, percent time speeding) will be recorded automatically for the four advanced capabilities scenarios during this part of the study. In addition, all drivers will respond to a simulation sickness questionnaire (see Appendix E). However, only the experienced drivers will answer questions for a second questionnaire (see Appendix B) concerning their assessment of the realism and usefulness between the simulator and a tractor-trailer. Expert instructors who will be monitoring individual driver's performance, will provide ratings for efficiency and safety for such variables as vehicle control, following distance, speed selection, braking, and shifting. The following table provides an overview of the procedure for the advanced capabilities assessment.

Truck Simulation Validation Research Design—Part 2, Advanced Capabilities

Group	Pre-Test	Scenario	IR	Break	Scenario	IR	Break	Scenario	IR	Break	Scenario	IR	Break	Post Test	Q
Novice n=8	BS	1	VC FD SS B S	→	2	VC FD SS B S	→	3	VC FD SS B S	→	4	VC FD SS B S	→	BS	SSQ
Exper. n=8	BS	1	VC FD SS B S	→	2	VC FD SS B S	→	3	VC FD SS B S	→	4	VC FD SS B S	→	BS	SSQ RUQ

Note: IR—Instructor's Ratings; Evaluation Criteria consists of VC—Vehicle Control; FD—Following Distance; SS—Speed Selection; B—Braking; S—Shifting; Q—Questionnaires; SSQ—Simulator Sickness Questionnaire; RUQ—Realism, Usefulness Questionnaire; BS—Basic Skills Test.

The proposed study will employ, if appropriate, a full-mission simulator with traditional control-display interfaces that mirror the reality of a tractor-trailer cab. This requirement is based on the FHWA-sponsored simulation market assessment study (1996) that surveyed the state of the art in simulation technology applicable to the commercial driver training, testing, and licensing environment. At the time of the market assessment, the Digitran SafeDrive 1000 (see Table 1) was recommended as a test bed for the Phase 2 empirical validation. However, the OMCHS will reassess the marketplace before conducting Phase 2 of the validation effort to determine what developments have occurred since those recommendations were made in identifying feasible simulator test beds. As with reassessment of the technology, the research design is also amenable to revision. The research design provided is a general framework for conducting Phase 2. However, the design provides for flexibility as the project develops. Phase 2 is expected to commence in 1999 starting with the marketplace reassessment. Part 1 and Part 2 of the validation process, including the marketplace reassessment is expected to take approximately 18 to 24 months. At the conclusion of Part 1 and Part 2, interim reports will detail research results, findings, and conclusions. Part 3, the longitudinal aspect of the study, will require an additional 18 months to complete. This comprehensive process should provide sufficient evidence to make conclusions and recommendations concerning the appropriateness of simulation for commercial vehicle operator training, testing, and licensing.

The final component of the OMCHS simulator program is the integration of the NADS in its research program. The NADS, which is under the stewardship of the NHTSA is a stand-alone, state-of-the-art, driving simulator dedicated to providing a national research tool for conducting advanced studies on highway-driver-vehicle systems. The NADS consists of an integrated real-time system providing realistic vehicle dynamics and large-scale motion cues combined with high-fidelity visual and audio cues presented to a subject driver. The NADS will provide the capability for evaluating advanced vehicle control, communication, and navigation technologies. The NADS will be located at the University of Iowa, Oakdale Research Park, Iowa City, IA, and is scheduled to become operational in spring 2000.

Table 1. Observations of the Functional Capabilities of the Digitran SafeDrive 1000 Truck Driving Simulator[1]

Capability	Judgment of Capability		
	Not Provided	Adequate	Not Adequate
1. Basic Operation 1.4 Basic Control			
1.4.1 Accelerating		✓	
1.4.2 Braking		✓	
1.4.3(a) Driving Forward		✓	
1.4.3(b) Driving Backward		✓	
1.4.4 Turning		✓	
1.5 Shifting		✓	
1.6 Backing		✓	
1.8 Proficiency Development			
1.8.1 Maneuvering in Restricted Quarters		✓	
1.8.2 Upgrades and Downgrades		✓	
2. Safe Operating Practice 2.1 Visual Search			
2.1.1 Attention Sharing		✓	
2.1.2 Mirror Interpretation		✓	
2.3 Speed Management		✓	
2.4 Space Management			
2.4.1 Gap Judgment		✓	
2.4.2 Following Distance		✓	
2.5 Night Operation	✓		
2.6 Extreme Driving Conditions			
2.6.1 Handling Slippery Surfaces		✓	
2.6.2 Overcoming Surface Resistance	✓		
2.6.3 Downhill Braking			✓
3. Advanced Operating Practices 3.1 Hazard Perception			✓
3.2 Emergency Maneuvers			
3.2.1 Emergency Braking		✓	
3.2.2 Emergency Steering		✓	
3.2.4 Brake Failure		✓	
3.3 Skid Control and Recovery			
3.3.1 Skid Control		✓	
3.3.2 Skid Recovery		✓	

[1]U.S. Department of Transportation (1996). *Commercial motor vehicle simulation technology to improve driver training, testing, and licensing methods: Final report.*

CHAPTER I
INTRODUCTION

Background

In 1985, the Office of Motor Carrier and Highway Safety (OMCHS) moved to help standardize novice tractor-trailer driver training with the publication of the "Model Curriculum for Training Tractor-Trailer Drivers", which incorporated the FHWA "Proposed Minimum Standards for Training Tractor Trailer Drivers" (1984). The "Model Curriculum," as it is known in the industry, is a broad set of recommendations that incorporates standardized minimum core curriculum requirements and training materials, as well as standards pertaining to vehicles, facilities, instructor hiring practices, graduation requirements, and student placement. Curriculum content includes the following areas: basic operation, safe operating practices, advanced operating practices, vehicle maintenance, and nonvehicle activities. The Model Curriculum recommends a gradual progression from classroom lessons, to laboratory lessons, to behind-the-wheel (BTW) driver training, first on the driving range and, ultimately, on the street.

Within the past several years, the OMCHS has also published training curricula for the motor coach industry and for the operators of twin 28-foot trailers. In addition, state licensing procedures for commercial motor vehicle operators have been revised to reflect the requirements of the Commercial Drivers License (CDL) program, which was implemented on April 1, 1992.

In 1986, the Professional Truck Driver Institute of America (PTDIA) was created by the motor carrier industry as a national, nonprofit organization to certify training programs offered by truck driver training schools that met PTDIA certification criteria. (On July 1, 1996, the Interstate Truckload Carrier Conference, now called the Truckload Carriers Association, assumed the management of the PTDIA.) The Model Curriculum, although modified to meet the needs of the PTDIA, is the fundamental base from which the PTDIA's certification criteria were derived. The primary difference between the two approaches is that the PTDIA curriculum does not include "observation time" in the total number of training hours; hence, the PTDIA total is 147.5 hours compared to 320 hours in the Model Curriculum. (It should be noted that new PTDIA Tractor Trailer Curriculum Standard guidelines were unveiled in January, 1999. The Behind-The-Wheel (BTW) hours in the new standard remained unchanged at 44 hours. However, the revised standard should be reviewed prior to conducting the Phase 2 empirical study. Also, the PTDIA name has been changed to the Professional Truck Driver Institute. The "of America" has been deleted since PTDI now certifies schools in Canada and Mexico.)

Unlike these kinds of developments, the use of training technology has not changed much in the past 10 to 15 years. Only within the past few years have truck driver training simulators come into their own in terms of functionality and affordability. This trend represents an excellent opportunity for a simulation validation study, particularly because at the 1995 OMCHS Safety Summit, motor carrier officials identified driver training as one of the top three safety issues affecting their industry.

The primary motivating factors behind the interest in simulation-based training are (1) to improve driver performance and enhance highway safety, (2) to improve training effectiveness while, at the same time, contain costs, (3) to enhance the CDL environment, and (4) to address concerns for the safety of trainees, state licensing personnel, and other road users. The use of simulators may also provide the industry with greater standardization by promoting replicable training, testing, and licensing procedures. With simulation, Commercial Motor Vehicle (CMV) training, testing, and licensing opportunities can be enhanced to include unusual or dangerous driving situations. Simulation will provide the driver with opportunities for insight into the handling expectations of the vehicle and his or her own driving capabilities. This is just one of the benefits, but many others have been speculated upon by the industry such as enhanced transfer of training and thus, reduced training time, and possibly even a reduction in crashes. Evidence of these benefits exists for simulation applications in other transportation industries, particularly in aviation. However, without a validation, the extent that simulation technology can promote the training, testing, and licensing of *tractor-trailer drivers* is questionable. This validation becomes particularly important, necessary, and timely with the advances of technology and implementation of intelligent transportation systems.

Purpose of the Study

The purpose of this study is to determine if evidence supports the use of simulation for CMV driver training, testing, and licensing. This study proposes to examine how simulation technology, compared with conventional methods, may facilitate and enhance tractor-trailer driver performance. The following specifically related questions will be considered as part of the validation study:

1. Does simulation promote more efficient and/or effective training for completing instructional objectives?

2. What is the effect of simulation-based training on the Pre-Street Range Test (PSRT)?

3. What is the effect of simulation-based training on the Final Examination Road Test (FERT)?

4. What is the amount of transfer for the simulation-based training group?

5. Can simulation adequately assess skill acquisition for basic operation and safe operating practices?

6. Does training method predict performance on the CDL?

7. Are there differences in performance on the CDL examination between drivers trained using simulation and those trained using conventional methods?

8. Does training method predict performance on the job?

9. Are there differences in job performance (e.g., accident rates, number of violations) between drivers trained using simulation and those trained using conventional methods?

10. Can simulation adequately assess driver ability for advanced capability skills?

11. Are there differences in driver performance between novice and experienced drivers for advanced capabilities?

12. Does the CDL score predict driver performance for advanced capabilities?

13. Is there agreement among experienced drivers on the usefulness and realism of the simulator for the presentation of advanced capabilities?

CHAPTER II
LITERATURE REVIEW

Simulators, as training devices, have a long and varied history beginning with World War II. At that time, simulators or flight trainers, as they were called, were developed primarily in response to the technological advances being made in flight control (i.e., cockpit instrumentation). Originally, flight trainers were mechanically activated procedures trainers. However, their complexity evolved with the advent of analog computers and modern simulator training became a possibility (see Valverde, 1968, for review).

Although first developed to train military pilots (Caro, 1988), operator-in-the-loop simulators have been used to train other skilled performance, such as locomotive operators (Mecaskey, 1979), tank commanders (Orlansky and Thorpe, 1989), and ship helmsmen (Wheatley, 1979). The National Aeronautics and Space Administration (NASA) has used simulation to acclimate astronauts to weightlessness, the nuclear industry to train reactor operators, civilian governments to train air traffic controllers, and commercial airlines to train pilots. Why has there been such widespread use of this particular technology? The answer to this question lies in its advantages over the use of traditional methods with actual equipment and devices.

A major advantage of simulation is that it allows the trainees, whether they are pilots, tank commanders, or locomotive operators, to train for emergency situations that occur only rarely. By repeatedly training in simulation, the trainee learns to handle the emergency instinctively should it ever occur during actual operations. Repeated exposure to low-frequency, high-risk events is an important advantage of simulator-based training. For example, in the case of driving, many drivers, despite numerous years and miles on the road, have not experienced many high-risk situations. As a result, they have not had the opportunity to learn and practice emergency and evasive driving maneuver countermeasures. Creating hazardous situations in a simulator provides the learning experience without posing a threat to personal safety. Simulation would allow driver trainees to practice emergency responses to situations such as tire blowouts, brake failures, road hazards, and bad weather conditions that are too dangerous for on-the-road training. A further advantage is that simulator-based training takes place in a controlled learning environment; therefore, standardized training sessions can be readily provided. One of the major benefits of standardized training is that it makes possible the development of normative training data. Normative data is important because it serves as a baseline for tracking training effectiveness improvements. In simulation, the physical training environment is also precisely controlled so that scheduling of training does not depend on variables such as, the weather or time of day. Simulation can also accommodate terrain- and weather-specific exercises by replicating different weather or terrain conditions and combinations, adding yet another advantage to this technology.

Because driving and flying are similar in that both take place in a dynamically changing environment, simulation seems an appropriate tool for the training of driving skills. However, until recently the development of ground vehicle simulators has lagged behind flight simulators.

One critical reason has been the former's requirement for good out-of-window visual scenery. Whereas flying requires limited out-of-window monitoring, principally for landings, out-of-window viewing is a critical and continual activity in driving. With simulation the driving environment is more complex in terms of replicating vehicle dynamics, various road terrains, types of vehicles, traffic congestion, and other vehicles. However, development of driving simulators has now become accelerated with the availability and continued enhancement of computer-generated imagery and other technology advancements.

Recently, under a contract supported by FHWA DOT (1996), the current status of the market was surveyed, including not only national, but international, manufacturing sources of commercial vehicle operation simulators. At that time, at least 15 manufacturers worldwide were involved in distributing and selling part-task to full-fidelity truck simulators. In January 1997, as reported at the Transportation Research Board's (TRB) annual meeting, more manufacturers were developing simulators for the marketplace. While the benefits seem obvious, particularly concerning driver risk reduction when training for dangerous maneuvers in emergency situations, episodes of simulator sickness have been reported.

Simulator sickness is a type of motion sickness. Motion sickness is usually associated with air and sea travel, but it is also a frequent occurrence in situations involving illusory motion, such as vehicle simulators. It has important implications for simulator-based training because of its potential to reduce the pool of trainee candidates. According to Durlach and Mavor (1994), everyone with a functioning vestibular system is more or less susceptible, with about 10 percent of the population seriously afflicted. The precise causation is unknown, but it is believed to be associated with mismatched input from the visual and vestibular systems. Symptom severity depends on the degree and duration of the stimulation (Lackner, 1989). The symptoms may include dizziness, headache, heavy breathing, cold sweating, pallor changes, and, more seriously, nausea and vomiting; and they frequently persist long after the participant is removed from the inducing environment. Studies have proved that bright imagery is more likely to induce sickness than are night-time scenes, and that wide fields of view cause more problems than near ones do (Helman, 1993). In studies conducted with the HYSIM simulator (a fully interactive driving simulator) at the FHWA Turner-Fairbank Highway Research Center, study participants experience simulation sickness (in varying degrees of severity) when they drive scenarios that include curve negotiation. However, simulator sickness can be mediated by brief periods of exposure to the driving scenarios. Even so, some persons are particularly susceptible to simulator sickness; namely, older adults. Routine screening for susceptible persons is a necessary precaution.

A second concern regarding simulator training is the lack of dangerous consequences following high-risk behavior. The student driver must generalize what has been learned in the simulator environment to the road environment for effective training to take place. The training must instill in the student driver the importance of risk aversive behavior. However, due to the lack of imminent physical danger, risk aversive behaviors may not be reinforced. It is suspected that this situation may give rise to learning irrelevant or ambiguous cues that later interfere with correct learning transfer. In contrast, Zeitlin (1997a) provides a good review of simulator studies addressing the issue of performance incentives. In his review of 106 studies, he concluded that consequential incentives or factors that influence subject simulator performance where performance has *real world* consequences were adequate for simulation aimed at certification and training.

Simulation Validity

Three distinct types of simulators are (1) engineering simulators, (2) research simulators, and (3) training simulators. Each has different criteria when considering validation. How then does one assess the validity of using simulation technology for training driving skills? According to Sanders (1991), the most usual validation methods are, first, to study transfer of training from simulation to reality and, second, to compare behavior between simulation and reality. Transfer studies have been primarily carried out in the case of training simulators, while direct correspondence is usually assessed when the major aim of the simulation concerns equipment design. Validation can be judged by the extent to which the real environment and simulator evoke similar driver response and behavior. Furthermore, changes in tasks should evoke corresponding changes in driver response and behavior (Weir and Bourne, 1995). In general, measures of response and behavior useful in validation include driver control actions and response, vehicle motion response, driver plus vehicle response and performance, and subjective ratings and commentary.

Most validation studies, however, typically have focused on affirming the "representativeness" of the technology. For example, Blaauw (1982) conducted a validation by comparing system performances and driver behavior with respect to speed selection and lane-keeping control in a fixed-base simulator with an instrumented vehicle. He used novice and experienced drivers. Based on driver performances, his findings showed that lane keeping control was comparable in both systems. Most recently Klee, Bauer, Radwan, and Al-Deek (1999) presented evidence of the validity of a driving simulator on forward speed. This type of validation research has been prevalent in the literature. Zeitlin (1997b) reviewed 106 simulation studies and found that many behavioral and psychological facets of operator performance critical to transportation are under represented in the research literature. The scope of the research focused rather on validating the extent to which specific simulation components, such as the motion base, have reflected operational reality. The reason for this has been a concern for internal validity. Kaptein, Theeuwes, and van der Horst (1996) identified potential sources of problems with internal validity as being (1) the limited or unacceptable resolution of a computer-generated image, (2) motion delays until vehicle position and images are updated, or (3) limited horizontal field of view. These sources distort the simulated driving environment and create situations that are not expected in reality, so response by the driver will not be valid for evaluating the research problem (not to mention simulation sickness). Kaptein et al. (1996) provides a nice overview of validation studies conducted with the TNO driving simulator (e.g., which visual information is important for valid research in a driving simulator) in the Netherlands.

In the United States, the Committee on Simulation and Measurement of Vehicle and Operator Performance submitted the report *Simulator Technology: An Analysis of Applicability to Motor Vehicle Travel (1992),* which outlines a strategy for determining the need, potential use, benefit, and complexity of simulator technology for promoting safer vehicle travel. The report provides details on simulator requirements in response to the identification of needs, as well as relevant driver research issues. It provides a guideline for establishing simulator specifications for a driving simulator.

The validation of simulation, however, for the training of a particular skill is most appropriately addressed through an assessment of whether that training actually transfers to the environment in such a way as to encourage skill proficiency and safe operating practices. Goldstein (1986) elaborated on the validation of simulation by distinguishing between training validity and transfer validity. In the former, improvement is done during training, and in the latter, improved performance transfers to the job. Measuring the relative effectiveness of training can be done by comparing performance in a simulator versus the real world. Goldstein identified three issues that need to be considered: (1) learning efficiency in the simulation, (2) transfer of learning to the real environment, and (3) retention of learning. He noted that most training evaluations have involved only the first of these issues. The following paragraphs identify research corresponding to each of the three issues.

Training Evaluation and Effectiveness with Simulation

Most often the effectiveness of training in a simulator can be assessed by determining how much training time in the real vehicle is saved by simulator training or learning efficiency. In general, the effectiveness of simulators is well documented, particularly in their most common application—flight training. Orlansky (1986) summarizes the results of numerous studies of flight simulators in military settings and concludes that with few exceptions training time in a simulator saved training time in the actual aircraft. The median percent transfer was 31%; that is, use of the simulator reduced the amount of equipment time required by 31%. Effectiveness results are more clear cut for simulators than for other training media because the transfer of training can be measured directly. Measures frequently used in the application of transfer formulas include: (1) the number of trials required to reach a given level of mastery, (2) the amount of time required to reach a given level of mastery, (3) the level of mastery reached after a given amount of time or number of trials, and (4) the number of errors made in reaching a given criterion of mastery. Results of different transfer studies can easily depend on ways in which transfer is measured; therefore, it is important to identify how transfer is measured and calculated when comparing the magnitude and direction obtained in different studies.

An example of transfer of learning to the real environment was demonstrated in a study by Koonce (1979). Koonce conducted research to determine the predictive validity of flight simulators. He stated that, at the time, specific data bearing on the predictive validity of simulator performance of airline pilots had not been made public. His research was based on the need for a systematic controlled investigation of the relationships between ground simulator pilot performance and aircraft pilot performance. The results show that simulation was effective in predicting pilot overall proficiency in performing the entire mission in the aircraft. Multiple correlations between multiple maneuver scores were correlated to observer ratings of the subject's performance. All correlations were positive and significant across time to perform the mission. A more recent study conducted by Miller, Stanney, Guckenberger, and Guckenberger (1997) demonstrates an improvement over conventional training with the use of simulation in the training of F-16 Air Force pilots. However, with respect to commercial driver training and simulation, there is a paucity in the literature, with most of the research focused on the psychophysical aspects of simulation. Studies conducted by Schmidt, Müller, and Trost (1993) and Dietrich (1995) have, however, focused specifically on truck driving instruction using simulation. Schmidt, Müller, and Trost (1993) compiled a heavy goods vehicle (HGV) driving simulation with a five-channeled outside view presentation. The practical testing of the driving simulator was carried out by eight student drivers who had no previous truck driving experience. The objective was to compare HGV training with both a real vehicle and the use of a simulator. Eight 30 minute driving lessons were completed in both the HGV and the simulator. Training consisted of 12 tasks, such as turning left, driving up gradients and down gradients, and maneuvering with trailers. Apart from the learning successes and failures of the student drivers, physiological parameters such as strain, fatigue, and state of health were investigated. Learning was completed by drivers without any significant problems. Regarding the health of the drivers, only a few problems with simulation sickness were identified for certain persons, who also suffered under other conditions from travel sickness. Lastly, student drivers were required to negotiate through real traffic. Even under the most difficult driving conditions, the drivers were certified as having good control of the vehicle. Compared with drivers who had been purely conventionally trained, drivers who were trained with the use of the simulator often gained better results. A study by Dietrich (1995) compared traditional truck driving instruction in the German military to an innovative driver training program using simulators. The experiment included nine 30-minute learning units in which each subject spent 30 minutes in either the simulator or the truck. Dietrich collected driver performance data; instructor ratings for tiredness and risk taking; and self-ratings for calmness, anticipation, and efficacy of learning from trainees. In terms of the criterion task, the final driving test, reliable differences between the groups indicated higher scores in the simulation-trained group. Allen and Stein (1990) reported that the DuPont Company had developed a simulator for teaching truck operators situational awareness, using a variety of driving scenarios with a variety of situations, including traffic patterns and weather. However, it is noted that the training effectiveness of the system had not been formally validated, at that time. This lack of validation appears to be a problematic trend, as noted by Kaptein et al. (1996).

As with transfer of learning, Goldstein's third issue of long-term retention of learning has not been thoroughly addressed, as these types of studies, while easy to define, may be hard to achieve in practice. The reasons include that these types of studies take a long time; require adequate control; and need the appropriate measures which may not be easily obtainable (e.g., employment histories). The proposed validation study described in this report has provisions to examine long-term learning, because it is important in properly and comprehensively addressing the issue of the appropriateness of simulation for the training of tractor-trailer drivers.

If simulation training can reliably produce differences between those trained on simulation and those trained with conventional methods, how might this technology be further used to promote safer drivers? Could simulation be used for the purpose of personnel selection? For commercial vehicle operation, the screening of new applicants would be a major advance toward identifying those drivers with a propensity for accidents. Arthur, Barrett, and Doverspike (1990) provide some support for the use of simulation as a personnel selection tool. They conducted a validation study to determine if the selection of petroleum-product transport drivers could be improved through the use of simulation. Arthur et al. (1990) used an approach based on construct validity for the laboratory simulation and a follow-up field study. However, their findings were constrained by a restriction of range because transport drivers with problematic driving records were self-selected out of the sample. Nonetheless, the study results provide a basis for examining the use of simulation for personnel decisions.

In addition to determining the effectiveness of simulation-based training, as compared to conventional truck-based training, it is the intent of the proposed validation research to examine the relationships between simulation-based proficiency tests and CDL performance and actual job performance for tractor-trailer drivers.

CHAPTER III
FACT FINDING

Over the years, the FHWA has encouraged private industry to advance the state-of-the-art in truck driving simulation. The simulation industry has risen to the occasion as is evidenced by the number and reduced costs of new truck simulators in the marketplace and enhancements to existing devices. The time is now ripe to assess the effectiveness and efficiency of simulation to improve truck driver training, testing, and licensing. This is particularly important given the lack of research in this area.

Because the focus of this report is to identify a research design that adequately validates this technology, a need emerged to better understand the requirements of the training and licensing environment. Also, benefits were to be gained from the advice of those knowledgeable in the heavy vehicle industry. The following paragraphs outline the events that contributed to the development of this report.

A preliminary outline of the initial, proposed research design and subsequent status update has been presented several times to the Committee on Simulation (A3B06) at the annual meetings of the Transportation Research Board. At one of these sessions, comments following the presentation centered on the need to ensure a reasonable criterion measure was used to benchmark the simulator training scores. The consensus was that employing expert judgments similar to those used in assessing airline pilots was the best approach. It was suggested that expert trainers could be used to provide those assessments. The final validation design incorporates these and other recommendations. Also considerable effort was directed toward developing simulated driving scenarios that could provide the appropriate out-of-window forward scenes, coupled with the training requirements for novice truck drivers. After a complete set of driving scenarios based on FHWA/PTDI Model Curriculum was thoroughly developed, a workshop was held on April 16, 1996, that included experts from the trucking industry, simulation experts, truck driver training experts, regulatory groups, the research community, OMCHS, and other government agencies. The objective of the workshop was to obtain input from external reviewers to further the scenario development process. A previous internal review of the first draft scenarios by the OMCHS/contractor team resulted in first-generation scenarios that served as input for this workshop. The output of the workshop was used to prepare the second-generation driving scenarios, which are included in Appendix A of this report. The following list includes the individuals who served as participants and reviewers:

Susan Allen, DC Bureau of Motor Vehicles
Dr. Wade Allen, Systems Technology, Inc.
George Beaulieu, Safety Awareness Through Fleet Education, Inc.
John McFann, North American Van Lines
Dr. Keith Brewer, National Highway Traffic Safety Administration
Dorothy Bryant, American Trucking Association and Safeway
James McKnight, National Public Services Research Institute

Mike Trembur, National Private Truck Council and Praxair
Dr. Truman Mast, Federal Highway Administration/Turner-Fairbank Highway Research Center
Jerry Robin, Office of Motor Carrier and Highway Safety
Ron Finn, Office of Motor Carrier and Highway Safety
Dr. James Fisher, Science Applications International Corporation
Dr. Cathy Emery, George Mason University

Given that the scenarios were based on the FHWA/PTDI Model Curriculum, major changes were not required. Of the changes, however, most concerned timing which was adjusted to reflect the actual PTDI BTW times. Scenarios for the advanced capabilities of the simulator were fine tuned and consolidated to capitalize on the technologies for the test bed at that point.

In addition to conducing the scenario review workshop, FHWA conducted informal interviews with representatives from the Department of Transportation, other U.S. Government agencies, Transport Canada, motor carrier industry training organizations, simulator vendors, and potential users. The Federal Aviation Administration (FAA) and NASA Internet web pages covering simulator activities and plans were also reviewed. Organizations contacted included:

American Trucking Associations Foundation
Canadian Trucking Association
Digitran Simulation Systems
FAAC, Inc.
Federal Aviation Administration
Federal Highway Administration,
Office of Safety Research & Development (Turner-Fairbank Highway Research Center)
I*SIM
National Aeronautics and Space Administration
U.S. Army
U.S. Coast Guard

In general, discussions with representatives of the motor carrier industry indicated that they favored the use of simulators for CMV driver training, yet they remain skeptical of the benefits claimed by simulator promoters. In short, many have adopted a wait-and-see attitude, although some larger motor carriers that provide in-house training currently employ simulation; such as North American Van Lines, which uses the FAAC simulator. Moreover, simulator vendors face competing demands from Intelligent Transportation Systems (ITSs) vendors for motor carrier investments in new technology. Not surprisingly, motor carriers expect solid evidence that driving simulators can reduce training costs before committing limited resources in that direction. By and large, the motor carrier industry has viewed simulators from a capital cost perspective. The capital cost approach stems from the view that simulators are no more than substitutes for trucks as training devices. Truck simulators do not stack up well when viewed this way, although capital costs are dropping. Simulator proponents believe a more appropriate analysis would look at the incremental training effectiveness of simulators vis-a-vis trucks.

Similar sentiments were expressed by a representative of the Trucksafe Learning Center (Edmonton, Canada) driver training school that uses the Digitran SafeDrive 1000.

The industry consensus on the use of simulators is that they will be used most effectively for remedial training and advanced training because of their ability to simulate failures and hazards that cannot be safely demonstrated in trucks. No hard evidence, however, supports these views. By far, the best evidence for the use of simulators for training skills dealing with hazardous situations is with the U. S. Army. Simulators have been used for not only individual combat training, but team combat training at Fort Knox (KY). Individual training is conducted for driver and gunnery positions in tank crews. In general, troops (drivers) trained with the use of simulation have been compared with conventionally trained troops on the range, and performance results have been comparable (Peterson and Johnson, 1989). In certain instances, performance has been better. While safety is of prime importance, the use of simulation is a cost-effective measure in containing the expense of training with live ammunition. The U.S. Army also uses simulated maintenance trainers for repairing heavy vehicles and for heavy vehicle driver training. The Army has exposed 12,000 novice trainees to some degree of simulator time over the past 4 years, indicating considerable support for the effectiveness of the technology. The FAA reports that more than 300 simulators are authorized for use by U.S. air carriers in all types of aircraft with 30 or more seats. The FAA also states that computer-based flight simulation has been the single most important advance in the field of aviation training. The FAA has ruled that in some cases, for certain classes of pilots, simulator training can completely replace actual flying time to meet training requirements. Proficiency assessment in a flight simulator is more economical and more readily controlled than is a similar evaluation in the air. In fact, these devices have proven to be so useful that virtually all flight segments for training airline pilots are given in simulators rather than in their counterpart aircraft. The FAA has recently initiated a program identified as Line Operational Evaluation that differs from previous flight simulation training in that an evaluative component has been included as part of the validation process. Instructors provide assessment for crew members.

Finally, the U.S. Coast Guard uses simulation for training personnel in ship handling skills. Simulators have been implemented at union schools and at seven academies for maritime training. Recently, an internal maritime forum focused on reviewing the training effectiveness of simulation and found that, although standards have been established based on mathematical models, few, if any, studies assessed whether learning was better with the use of simulation.

Because simulation is prevalent in the training of diverse skilled performance, it seems reasonable that this technology is receiving support for the training of tractor-trailer drivers. However, unreserved acceptance of the technology without research to examine its effectiveness for the training of tractor-trailer drivers is not prudent. Therefore, the rest of this report reflects the design and methodology for an empirical evaluation to substantiate this technology for the training, testing, and licensing of tractor-trailer drivers. A preliminary draft of this design was submitted to a peer review in June, 1997 that included researchers, simulation experts, experts in truck driving training, distinguished members of the heavy vehicle industry, regulators, and U. S.

and international government personnel. Participants included the following individuals and organizations:

Dr. Wade Allen, Systems Technology, Inc.
Lana Batts, Professional Truck Drivers Institute of America
George Beaulieu, Safety Awareness Through Fleet Education, Inc.
Dr. Keith Brewer, National Highway Transportation Safety Administration
Francisco Carrion, Instituto Mexicano Del Transporte
Robert Carroll, ASA, Inc. (currently, Office of Motor Carrier and Highway Safety)
Virginia DeRoze, Professional Truck Drivers Institute of America
Dr. Cathy Emery, George Mason University
Ron Finn, Office of Motor Carrier and Highway Safety
Stephen Fleger, Science Applications International Corporation
Dr. Ron Knipling, Office of Motor Carrier and Highway Safety
John McFann, North American Van Lines
James McKnight, National Public Services Research
George Reagle, Office of Motor Carrier and Highway Safety
Jerry Robin, Office of Motor Carrier and Highway Safety
Brett Robinson, American Association of Motor Vehicle Administrators
Chuck Rombro, Office of Motor Carrier and Highway Safety
Sesto Vespa, Transport Canada
Jerry Wachtel, The Veridian Group

The results of that workshop provided a refinement of the original design. Much discussion centered around issues previously identified in this report, such as measures of performance, points for the longitudinal test aspect, data collection, and logistics. Those revisions are reflected in the next chapter of this report.

CHAPTER IV
APPROACH

The OMCHS is embarking on a validation effort for the use of simulation for the training, testing, and licensing of tractor-trailer drivers. This effort will require that a validation "process" be implemented to address the appropriateness of using simulation technology for each of the specific applications. The validation of simulation-based *training* incorporates a transfer of training paradigm (Part 1). This type of design allows for the comparison of training effectiveness, while the CDL will be the criterion task for providing evidence that simulation-based training results in, at the least, no worse performance on the licensing examination. However, the validation for *testing* using simulation requires determining the predictive validity of the in-course tests. Therefore, the Pre-Street Range Test (PSRT) and the Final Examination Road Test (FERT) will require relating performance measures (i.e., test scores) to the CDL and job performance. A need also exists for examining correlations between the respective versions (i.e., simulation-based and truck-based) of the tests to establish convergent validity; the tests should positively correlate with each other and thus demonstrate similar skills assessment. Next, assessment of the advanced driving capabilities using simulation (Part 2) demonstrates potential applications to enhance the *licensing* environment. The entire validation process, including the marketplace reassessment, but excluding the longitudinal aspect, is expected to take approximately 18 to 24 months. However, at the conclusion of Part 1 and Part 2, interim reports will detail research results, findings, and conclusions. Lastly, the longitudinal part of the study will require approximately 18 additional months (Part 3). This comprehensive process should provide sufficient evidence to make conclusions and recommendations concerning the appropriateness of simulation for CMV training, testing, and licensing.

The decision to use a simulator for training instead of employing the actual equipment has been justified by arguments such as higher utilization, increased safety, lower purchase and operating costs and the opportunity afforded to practice situations that cannot be readily provided in real-world conditions (Kanis, 1994). While these factors should be taken into account when deciding whether to opt for some form of "off-the-job" training, they are, by themselves, not valid criteria for assessing the appropriateness of a simulator as the training device. The primary aim of validating simulation technology is to determine the extent that it facilitates effective training to take place. To achieve this aim, the nature of the device required for the training purpose must be defined in a thorough manner and its training effectiveness objectively measured.

Training effectiveness can be measured in terms of trainee performance improvements and/or by relating training performance to job performance. The latter approach captures transfer of training effects. The determination of training effectiveness requires three essential steps. First, appropriate measures of trainee performance must be established; second, a research design must be developed so that changes in performance that have occurred during or shortly after the training process can be measured; and third, the criterion measure of performance must be objective. The following pages reflect this approach beginning with the hypotheses concerning the outcomes of the validation process.

Hypotheses

In consideration of the driver tasks and requirements in the validation of simulation for the training, testing, and licensing of tractor-trailer drivers, the following research hypotheses are candidates for testing:

Forward Transfer of Training

Hypothesis 1

It is predicted that training method will promote driver training effectiveness. Specifically, student drivers receiving simulation-based training will require (1) fewer training trials and (2) less training time to obtain instructional objectives per unit and per component of instruction than student drivers receiving conventional training.

Hypothesis 2

It is predicted that training method will have a facilitative effect on in-course driver testing. Specifically, student drivers receiving simulation-based training will (1) obtain equal or higher scores and (2) require equal or less time to obtain a passing score on the PSRT and the subsequent FERT than the conventionally trained student drivers.

Hypothesis 3

It is predicted that training method will have a facilitative effect on driver licensing performance. Specifically, student drivers receiving simulation-based training will obtain the same or higher scores on the driving skills tests of the CDL examination than student drivers receiving conventional training .

Hypothesis 4

It is predicted that training method will have a facilitative effect on subsequent short-term (3 months) and long-term (12 months) driver performance. Specifically, student drivers receiving simulation-based training will have better safety records reflecting (1) fewer number of accidents, (2) fewer number of "points" on driving record, (3) fewer number of citations, and/or (4) higher supervisory ratings than student drivers receiving conventional training. Student drivers receiving simulation-based training will also have a lower industry attrition rate than student drivers receiving conventional training.

Hypothesis 5

It is predicted that simulation-based in-course tests (PSRT & FERT) will have a significant positive correlation with conventional-based test versions.

Hypothesis 6

It is predicted that simulation-based performance measures (run time and number of accidents/incidents) will have a significant positive correlation with instructor's ratings (mean efficiency and safety ratings).

Advanced Capabilities

Hypothesis 7

There will be a positive relationship between expert instructor ratings and driver performance.

Hypothesis 8

Experienced and novice truck drivers' performance for basic skills and safe operating procedures will show reliable differences. Experienced drivers will have an overall better level of skills.

Hypothesis 9

There will be improvements in performance between the pre-test and post-test for basic skills and safe operating procedures for all of the drivers. The magnitude of the differences between the experienced drivers as compared to the inexperienced drivers should attenuate.

Hypothesis 10

Experience will have an effect on performance. Experienced drivers will have better overall performances for the driving scenarios compared to the novice drivers.

CHAPTER V
RESEARCH DESIGN AND EXECUTION

This chapter is divided into two major sections. The first section provides an overview of the research design and comprises three parts: (1) a forward transfer of training, (2) an advanced capabilities assessment, and (3) a longitudinal component. The second section of this chapter describes the method proposed for each part of the study. Subsections include discussions of the subjects, scenarios, design, and procedures, and the measures of outcome performance for each part of the study.

Overview of the Research Design

Part 1 of the validation study will employ a forward *transfer of training* (TOT) paradigm (see Table 3). In general, when the TOT paradigm is used to test training effectiveness, the experimental design should include a control group that receives training and at least one experimental group that receives an equivalent amount of different training. In addition, both groups should also be given an appropriate test on the criterion task. This research design includes a control group that will receive the conventional (truck-based) behind-the-wheel (BTW) training and an experimental group that will receive approximately 66% of its BTW training in a simulator on peer-reviewed scenarios and approximately 34% of its BTW training in a truck (see Table 2). Both groups will progress through all of the training units contained in the FHWA/PTDI Model Curriculum for tractor-trailer drivers. Embedded in this design is the administration of two truck-based, in-course tests, the Pre-Street Range Test (PSRT) and the Final Examination Road Test (FERT). However, a simulation-based version will be developed for both tests and administered in addition to the truck-based version, as part of the training/testing sequence (see Table 3, Part I). This part of the testing sequence will allow for an assessment of the equivalence of the simulation- and truck-based tests. Upon completing the curriculum, both groups will attempt to pass the Commercial Drivers License (CDL) examination, which will serve as the criterion task.

Part 2 of the study will examine *advanced capabilities* (see Table 4) of tractor-trailer driving, thereby demonstrating the potential of simulation. Simulation appears to lend itself particularly well to driving situations that are dangerous, unusual, or infrequently encountered. However, there exists the opportunity to separately assess simulation-based advanced capabilities for potential Commercial Motor Vehicle (CMV) licensing applications. For this part of the study, a two-group pre-test, post-test design will be conducted with novice and experienced truck drivers having their performances compared on select advanced skill-level driving scenarios. Measures of performance will include objective data, such as the number of lane deviations, percent of time speeding, and fuel economy. These measures will be collected automatically by the data capture capability of the simulator. Subjective data, such as expert ratings, will be collected through direct observation (see Table 4).

Part 3, the final part of the study (see Table 3, Part 3), determines the effect of hybrid conventional/simulation-based training on job performance outcomes, compared to student drivers who received their training under conventional training. Student drivers who successfully pass the CDL and remain employed for at least 12 months will be included in this part of the study. For this particular validation effort no externships will be included, so as to ensure the relative long-term comparability of the two groups.

NOTE: All parts of the research design and the simulation-based driving scenarios were submitted to an extensive peer review process. The research design presented here reflects many of the suggestions of the peer review participants.

Pilot Study

Pilot studies will be conducted for both the forward TOT (Part 1) and the advanced capabilities assessment (Part 2) to address any potential problems (e.g., logistics or data collection and/or data analysis). The pilot study for the forward TOT will focus on the simulation-based training method. The pilot study, at a minimum, will involve eight (8) student drivers and two instructors. Two student drivers will be assigned to each of the subgroups. In the actual experiment, each BTW instructor will have three, or possibly four, student drivers at a time to train, as recommended by the PTDI. However, only one student driver at a time will receive hands-on BTW training. The other students will be engaged in passive learning. Therefore, it seems unnecessary to have more than one student driver in a passive learning mode during the pilot, particularly when subjects may be at a premium for the actual study. Two candidate scenarios will be selected from those developed for the training phases (i.e., Basic Operation and Safe Operating Practices) of the *forward TOT design.*

The *advanced capabilities assessment* pilot testing will require that the following four scenarios be used in exercising the procedures outlined in the Methods section: Unit 1.9—Special Rigs; Unit 2.3— Speed Management; Unit 2.6—Extreme Driving Conditions; or Unit 3.2—Emergency Maneuvers. At least four drivers, two experienced and two inexperienced will participate in the advanced capabilities assessment pilot. Further guidelines for developing the pilot for both the forward TOT and the advanced capabilities assessment can be found in the Method section of this report.

Finally, instructors' assessment of driver's performance is a critical aspect for both the TOT and the advanced capabilities assessment and must be given careful consideration. There can be a strong moderating effect on training outcomes due to the behavior of the instructor. It is particularly important that the instructors feel comfortable with the simulated training environment. Therefore, instructors with a bias either for or against simulation-based training should not be used in any part of this study.

Method

Forward Transfer of Training

Subjects

Forty-eight (48) volunteer student drivers (see NOTE below) will be solicited from an appropriately licensed driving school or motor carrier that provides driver training. Provisions will need to be made to actually recruit more candidates than the target number to allow for student driver attrition. Student driver attrition is anticipated to be a problem in the short-term, and particularly as it relates to the longitudinal component of the study; the industry drop-out rate for commercial drivers is 50% after 18 months. For this reason, a screening tool will need to be developed to identify the student drivers for the study. Subjects will be required to participate in a multiple hurdle screening process that will include possessing a good driving record, passing a simulator sickness screening test (Kennedy, Lane, Berbaum, & Lilienthal, 1993; see Appendix E), and meeting selection criteria on the other screening tools (e.g., Biographical Application Blank, Weighted Application Blank). Furthermore, all subjects will be required to (1) possess a valid commercial driver learner's permit, and (2) meet all requirements specified in the Federal motor carrier regulations, including state medical, age, and drug and alcohol testing. All students will have to be residents of the state where the training and subsequent CDL examination will take place. Administering the CDL in a single state allows for a limited number of state examiners and, thus better internal control for the integrity of the study. Although selective placement will introduce bias into the study (in terms of an unrepresentative sample of student drivers), it is considered necessary to maintain an intact subject pool throughout the life of the study. The final pool of student truck drivers selected for the study will be randomly assigned to one of the two training method groups. Stratified randomization will be implemented to assure proportional representation of male and female student drivers.

NOTE: Forty-eight subjects is a minimum suggested target number representing a 3:1 student driver to instructor ratio. This ratio may, in fact, be altered to a 4:1 ratio, if necessary. The number of subjects selected for this study will be contingent upon meeting this ratio and in consideration of the 50/50 split into subgroups for assignment to the two versions of the in-course examinations. Therefore, 60 subjects should be recruited to assure the target number of 48 will be obtained.

Scenarios

The following scenarios will be incorporated into the modified PTDI curriculum for the simulation-based training group: Units—1.4 Basic Control; 1.5—Shifting; 1.6—Backing; 1.7—Coupling & Uncoupling; 1.8—Proficiency Development; 2.1—Visual Search; 2.2—Communication; 2.4—Space Management; 2.5—Night Operation; and 2.7—Proficiency Development. Each of the scenarios corresponding to the aforementioned units are described fully, including task objectives and PTDI hours of instruction, in Appendix A. Units 1.1 through

1.3, 1.9, 2.3, and 2.6 do not have BTW requirements and, therefore have not been adapted for simulation-based training.

Simulator

The FHWA published a report, *Commercial Motor Vehicle Simulation Technology: To Improve Driver Training, Testing, and Licensing Methods* (DOT Publication No. FHWA-MC-96-003, 1996), on the functional requirements of CMV simulators. The report provides an assessment of each simulator for functional requirements based on CMV driving objectives. It was proposed, at that time, that a full-mission, state-of-the-art simulator, such as the Digitran SafeDrive 1000, would be necessary to meet driver training functional criteria, as well as driver licensing issues. However, since that report was originally published, the truck simulation marketplace has seen a host of new products and enhancements and as such, the final decision regarding simulator(s) selection will be determined on reassessment of the marketplace before conducting the actual empirical validation study.

Design

For the TOT, a 2 (training phase: basic operation and safe operating practices) x 2 (training method: conventional tractor-trailer vs. simulation) mixed repeated measures design will be used for this part of study. Training method is the between-subjects variable and training phase is the within-subjects variable.

Training phase will consist of scenarios based on units within the two componential skill development phases:(1) Basic Operation and (2) Safe Operating Practices. These two phases represent a functional division in the curriculum whereby further instruction in Safe Operating Practices is contingent upon skill acquisition in Basic Operation.

Training method will vary based on the percent of BTW hours allocated to simulation. The design makes the distinction between a control group receiving conventional truck-based training and an experimental group receiving primarily simulation-based training. Specifically, student drivers in the experimental group will receive about 66% of their required total BTW hours in simulation and about 34% of their BTW hours in a tractor-trailer.

BTW Hours. The PTDI curriculum recommends that a minimum of 44 clock hours be completed to satisfy the BTW requirements. Table 2 outlines the proposed allocation of BTW hours per unit of instruction per training phase per training method. For example, under Basic Operation, Unit 1.4—Basic Control, the PTDI requirement is for 2.25 BTW hours, as indicated in the column labeled "Conventional Truck Hrs." In contrast, under the column labeled "Experimental," student drivers will receive 1.5 hours BTW in simulation, leaving .75 BTW hours for training in an actual tractor-trailer. As shown in Table 2, the total BTW for both conventional and experimental groups is 44 hours (in the experimental group, the 44 BTW hours comprises 30 simulator BTW hours plus 14 truck-based BTW hours).

Table 2. Behind-the-Wheel (BTW) Hours Allocation to Groups

		Conventional	Experimental	
a. Basic Operation		Truck Hrs	*Sim Hrs*	Truck Hrs
Unit				
1.4	Basic Control	2.25	1.50	.75
1.5	Shifting	.75	.50	.25
1.6	Backing	7.00	5.00	2.00
1.7	Coupling & Uncoupling	1.00	.75	.25
1.8	Proficiency Development	15.00	10.00[1,2]	5.00[1,2]
	Total	**26.00**	**17.75**	**8.25**
		Conventional	Experimental	
b. Safe Operating Practices		Truck Hrs	*Sim Hrs*	Truck Hrs
Unit				
2.1	Visual Search[1]	2.50	1.75	.75
2.2	Communication	1.00	.75	.25
2.4	Space Management	1.75	1.25	.50
2.5	Night Operation	2.25[2]	1.50[2]	.75[2]
2.7	Proficiency Development	10.50	7.00[1]	3.50[1]
	Total	**18.00**	**12.25**	**5.75**
	Grand Total	**44.00**	**30.00**	**14.00**

[1] Requires LOW- and HIGH-density traffic.
[2] Includes Range + Street BTW.

Table 2 identifies only the BTW requirements of units in Basic Operation and Safe Operating Practices that have been adapted for simulation-based training. Each student driver will be required to meet all the instructional objectives and hours of instruction including classroom and lab for the entire PTDI tractor-trailer curriculum (see Appendix C). As discussed on page 1, the BTW hours for the new PTDI curriculum standards remain unchanged at 44 hours. This report, however, reflects the "old" standard, as revised by the peer review groups. A decision whether or not to use some or all of the new PTDI curriculum requirements will need to be made when Phase 2 commences.

In attempting to address research questions pertaining to simulation-based training effectiveness, it will be necessary to examine student driver's performance on the basis of how readily the instructional objectives are obtained. For any given unit, student drivers will initially require direct guidance from the instructor in completing the instructional objectives. After satisfying those objectives, student drivers will then have the opportunity to practice for skill development until it is time for the next student driver to begin BTW instruction.

As mentioned earlier, the role of the instructor in providing accurate assessment of student driver training will be critical. Each of the instructors will be required to maintain a record of (1) the number of training trials per unit and (2) the time it takes the student driver to satisfy the objectives for each unit. Since, as a matter of standard practice, the instructors must maintain daily logs on student driver progress through the units, it should not seem overly burdensome for them to keep track of the number of training trials and training time required across the 10 BTW units. Anecdotal notations concerning the amount of verbal prompting or physical prompting will also be collected as supplemental sources of information to document driver training progress.

To control for the moderating effect that may occur because of the differences among individual instructor(s), instructor assignment will be changed after completing the units on Basic Operation; each student driver will be taught and evaluated by two (2) instructors. (Note: There will be four instructors between the training methods; two (2) for conventional training and two (2) for simulation-based training).

In-course Tests. In addition to meeting the requirements for the instructional units, student driver performance will be assessed on two in-course skills tests, the PSRT and the FERT. The PSRT will be attempted after completing Unit 1.8—Basic Operations Proficiency Development while the FERT will be attempted after Unit 2.7—Safe Operating Practices Proficiency Development. Student drivers must meet specific criteria on these tests to progress through the curriculum (see Appendix D). If a student driver does not pass either the time or skill requirements of the truck-based, in-course tests, he or she may participate in retraining and attempt the tests a second and final time. Both of the in-course tests have traditionally been performed in a truck. As mentioned previously, simulation-based versions will be developed and administered as part of this study. Student drivers participating in both training groups will attempt both versions of the PSRT and FERT tests. The tests will be administered consecutively and counterbalanced to control for any adverse effects of order. Specifically, student drivers receiving simulation-based training will complete the units on Basic Operations; practice those skills during proficiency development; and then be divided into two subgroups of equal number (n=12), as shown in Table 3, to attempt the PSRT in the truck and in the simulator. Having passed the truck-based version, students will continue with PTDI training and attempt the FERT. No contingency is attached to the simulation-based in-course tests, and continued participation in the training curriculum is based only on passing the truck-based versions of the PSRT and the FERT.

The rationale for the "training-testing-testing" sequence is to examine the effect of training on the tests and to determine whether there is equivalence between the two test versions (i.e., simulator and truck-based). After completing all instructional units and proficiency development, and after passing the truck-based, in-course examinations, the student drivers will attempt the CDL examination.

In addition to addressing research questions concerning the effectiveness of simulation training and the appropriateness of simulation for testing tractor-trailer drivers, interest has emerged in whether simulation-based training ultimately results in reliable differences in driver performance. The response to this interest requires an examination of the student driver's post-training record. Driver records will be examined at 3 months and 12 months after obtaining the CDL, as a means of determining any short-term or long-term effects. Reasonable indices of driver successfulness on-the-job would seem to include the following: (1) number of accidents, (2) number of citations, (3) number of points on driving record, and (4) supervisory ratings. These measures will need to be finalized after reviewing the availability of access to driver records.

Table 3 provides an overview for the forward TOT (Part 1) and longitudinal component (Part 3) of the validation design. It depicts the aforementioned sequence of training and testing for the in-course evaluations (PSRT & FERT) and the CDL test. The study also provides for a second simulator should, at the time, resources become available to conduct this extended aspect of the study.

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Table 3. Truck Simulation Validation Research Design—Parts 1 & 3

		Part 1—Forward Transfer of Training (TOT)									Part 3—Longitudinal Component	
		Training/Testing Sequence									*Performance Sequence*	
Group	**% of BTW Allocation of Hours**	***Basic operation***	**Proficiency Development**	**PSRT**	**PSRT**	***Safe operating practices***	**Proficiency Development**	**FERT**	**FERT**	**CDL Test**	**Job Performance 3 Months**	**Job Performance 12 Months**
Conventional n = 24 (12 subjects in each subgroup)	100% Truck 0% Simulator (T = 44 hours) (S = 0 hours)	Units 1.4 -1.7	Unit 1.8	T S	S T	Units 2.1-2.6	Unit 2.7	T S	S T	T	✦Supervisory Ratings ✦Accidents ✦Citations ✦Driver Comments	✦Supervisory Ratings ✦Accidents ✦Citations ✦Driver Comments
Experimental n = 24 (12 subjects in each subgroup)	34% Truck 66% Simulator (T = 14 hours) (S = 30 hours)	Units 1.4 -1.7	Unit 1.8	T S	S T	Units 2.1-2.6	Unit 2.7	T S	S T	T	✦Supervisory Ratings ✦Accidents ✦Citations ✦Driver Comments	✦Supervisory Ratings ✦Accidents ✦Citations ✦Driver Comments

(Optional) Second Simulator Device

Experimental n = 24 (12 subjects in each subgroup)	34% Truck 66% Simulator (T = 14 hours) (S = 30 hours)	Units 1.4 -1.7	Unit 1.8	T S	S T	Units 2.1 -2.6	Unit 2.7	T S	S T	T	✦Supervisory Ratings ✦Accidents ✦Citations ✦Driver Comments	✦Supervisory Ratings ✦Accidents ✦Citations ✦Driver Comments

Note. BTW—Behind-the-Wheel; T—Truck-based test; S— Simulation-based test; PSRT—Pre-Street Range Test; FERT—Final Examination Road Test & CDL—Commercial Drivers License. General Information: PTDI Curriculum = 147.5 training hours (103.5 class/lab + 44 hours BTW). PTDI has revised the curriculum requirements, but BTW hours remain unchanged. Performance Measures: Number of training trials for each training objective and amount of time to reach the training objective. The design allows for inter- and intra-group comparisons.

Procedure

All student drivers participating in the TOT part of the study will complete a confidential questionnaire. Students will provide medical information, such as the name of any medication(s) they may be taking at the time. (Confidential information will be used only to help account for true differences obtained during performances.) In addition, each student driver will complete questions concerning basic skills experience, particularly as it relates to the previous use of large equipment operation (e.g., farm equipment), types of trucks driven, etc.

Student drivers will then receive an orientation and familiarization drive in the simulator before beginning training. During orientation, student drivers participating in simulation-based training will receive assurance that the nature of their individual training will not be divulged to licensing examiners. This precautionary measure will prevent potential bias for or against simulation by the examiner of the state licensing agency. However, the state licensing agency's officials and examiners will be made aware of the study. Student drivers participating in simulation-based training will also be given a thorough briefing about the allocation of their BTW hours to simulation and truck. In addition, these student drivers will be assured that they will receive some limited remedial training should simulation prove to result in a systematic bias toward lowered scores or higher failure rates either during training or on the PSRT, FERT, and CDL. Student drivers will be briefed on their opportunity for remedial training and re-test on the PSRT and FERT. However, FHWA will not guarantee that *all* student drivers participating in the project will pass either the training program or the CDL test. The conventional group will also participate in the orientation because of their simulation-based PSRT and FERT performances. All student drivers will need to become acclimated to the simulated driving environment and, in particular, to any function or control that has been modified from a truck (e.g., the mirrors are represented as screens) or that does not exist in the simulator. The orientation process may be developed from demonstration scenario(s) already available through the simulator manufacturer or owner. In addition, instructors will require an orientation to the simulated driving environment. After completing the orientation process, student drivers will complete a second questionnaire (see Appendix E) to identify any sensitivity to simulation sickness. This precautionary procedure will help with participant retention in the program.

Each student will then participate in a classroom lesson with demonstration by the instructor for the respective units. For the BTW requirement, each student driver will participate in a three-person (recommended) or four-person (maximum) group assigned to a single instructor. On a rotating basis, one student driver will receive hands-on training at the wheel, while the other student drivers directly observe the performance. Depending on training method, observation will take place from either the instructor's station associated with the simulator or from inside the cab of the truck. Each student driver will progress through the PTDI curriculum unit by unit (some units modified), following all established procedures, and meeting instructional objectives.

The procedure through the curriculum units for student drivers in simulation-based training will begin with BTW training in the simulator. After the instructor has determined that the student driver has obtained the BTW instructional objectives of the unit, he or she can continue to practice the maneuvers in the unit. The student will be allowed to practice until the BTW time allocated to the simulator has been met. Then the next student driver in the group will participate in simulation-based training, and so on. After each student driver has completed the simulation-based BTW portion of the unit, they will transfer to the truck to complete practice for the BTW time for that unit.

All student drivers will begin with Unit 1.1 and will progress through all units of Basic Operation (see Table 3) until they are ready to attempt Unit 1.8—Proficiency Development and the PSRT. Upon obtaining a passing score on this in-course examination, the student drivers will continue their training on the units for Safe Operating Practices (see Table 3). After completing these units, the student drivers will attempt Unit 2.7—Proficiency Development and, subsequently, the FERT. After passing the final examination test battery, student drivers may then attempt the CDL. Student drivers will be allowed only one opportunity to pass the CDL in this study (although they will be free to pursue the CDL on their own). Before attempting the CDL, student drivers will receive a debriefing at the completion of the curriculum. During the debriefing, it will be stressed that they should not disclose to any licensing authority that they participated in simulation-based training. Such non-disclosure is necessary to avoid any potential bias directed toward the type of training they received.

Measures of Outcome Performance for the Transfer of Training

Training Trials. The number of attempts by the student to reach criteria for a performance objective during the instructional phase of the BTW requirement will be recorded by the instructor. A record will be maintained for each unit, and a composite number of trials will be determined for both the control and experimental groups across the component training phases. Assessing the total number of training trials per phase will allow for determining whether simulation may be better for the training of certain component skills (i.e., basic control versus Safe Operating Practices).

Training Time. The total amount of time to reach training objectives will be recorded for each of the 10 BTW units. Composite training times will also be calculated for both the control group and experimental group across each of the training phases.

PSRT Performance. Scores from the Pre-Street Range Test (see Appendix D) will be used to determine student proficiency for curriculum units on basic operation (see Part 1, Table 3). This test will be administered by the instructor after the student driver has obtained the BTW instructional objectives. The test consists of 63 maneuvers with a pass/fail scoring criteria (see Appendix D). Each maneuver is evaluated with performance and time criteria. Student drivers must pass 75% of these maneuvers within the specified time. When a student requires double the specified amount of time to complete any particular performance maneuver, a fail rating is assigned to the entire performance unit. Outcome performance will be collected for the total correct number of maneuvers, as well as total time to complete the test.

FERT Performance. Scores from the Final Examination Road Test (see Appendix D) will be used to determine student driver proficiency for curriculum units on safe operating practices (see Part 1, Table 3). The FERT has the same maneuver requirements and performance criteria as the PSRT. However, performance on the maneuvers must be completed under narrower lane widths and within less time than the PSRT. To achieve a passing score, students must successfully complete 75% of the maneuvers within the specified time period. Students requiring twice the allocated time to perform an exercise will receive a fail rating for the entire performance unit. Total correct number of maneuvers, as well as total time to complete the test, will be collected.

CDL Performance. The CDL examination (see Part 1, Table 3) is administered by the individual states with guidelines from the U.S. Department of Transportation, FHWA, Office of Motor Carrier and Highway Safety. In general, this test is required to have a knowledge test and a driving skills test. The knowledge test must consist of at least 30 questions, of which the applicant must pass 80%. To pass the driving test requires that the applicant pass all three parts: (1) vehicle inspection, (2) basic control skills, and (3) the road test. Each part has a separate passing criteria. Outcome performance will be measured by the total number of correct items on the driving skills test.

3-Month Job Performance. Performance measures (see Part 3, Table 3) will be collected from each student driver's professional record. These measures will include number of accidents, number of citations, number of points on driving record, and supervisory ratings. In addition, interviews will be conducted with drivers to elicit their impressions concerning the effect of their respective training experiences.

12-Month Job Performance. Performance measures (see Part 3, Table 3) will be collected from each student driver's professional record. These measures will include number of accidents, number of citations, number of points on driving record, and supervisory ratings. Driver interviews will be conducted for comments on the effect of their respective training experiences.

Advanced Capabilities (Part 2)

Subjects

Experienced (n = 8) and novice truck drivers (n = 8) will be recruited for this part of the study. Experienced truck drivers will have at least 15 years of professional driving experience and a tenure of at least 2 years with the same carrier, with no recordable accidents or citations for 3 years. Novice truck drivers will be a subset of those students who participated in the conventionally trained group of the forward TOT who obtained their CDL. Novice truck drivers participating in this study will be state residents.

Scenarios

Four training scenarios developed for simulation highlighting emergency/dangerous driving situations and simulated operations of doubles and triples are proposed for the advanced capabilities phase of the validation. These scenarios are part of those derived from the units within the FHWA Model/PTDI Curriculum for Training Tractor-Trailer Drivers. However, the advanced capabilities assessment will not include further skill development, but it will assess the usefulness, realism of the task, and appropriateness of simulation for potential training, testing, and licensing applications. The proposed scenarios are Unit 1.9— Special Rigs (SR); Unit 2.3—Speed Management (SM); Unit 2.6—Extreme Driving Conditions (EDC); and Unit 3.2—Emergency Maneuvers (EM). The scenario for special rigs will include exercises in driving different vehicle configurations, including multiple combination vehicles, such as doubles, triples, and liquid tankers. Emergency maneuvers will include exercises on evasive maneuvers, brake failure, and tire failure. Speed management will include exercises for controlling speed for safe operation and braking and stopping. Finally, the extreme driving conditions scenario will include exercises in emergency ramping, gusting wind, and icy highway driving in the mountains. Each of these scenarios is fully described in Appendix A, BTW Training Scenarios.

Note: ***At the time the validation study is conducted, all scenarios may need to be revised to reflect the capabilities of the selected simulator(s).***

Simulator

See "Simulator" section under Forward Transfer of Training for description.

Design

For the advanced capabilities, a 2 (Skill level: Experienced vs. Novice) x 4 (Scenario: EM vs. SR vs. SM vs. EDC) mixed design is proposed. Skill level is the between-subjects variable and scenario is the within-subjects variable. Skill level will consist of two groups of truck drivers that differ on the basis of the level of their professional driving experience (i.e., experienced or novice). Scenario will include the four scenarios identified in the preceding paragraphs. The order of presentation of the scenarios will be randomized independently for each subject. Table 4 provides an overview of the design.

Table 4. Truck Simulation Research Design—Part 2, Advanced Capabilities

Group	Pre-Test	Scenario	IR	Break	Scenario	IR	Break	Scenario	IR	Break	Scenario	IR	Break	Post Test	Q
Novice n = 8	BS	1	VC FD SS B S	→	2	VC FD SS B S	→	3	VC FD SS B S	→	4	VC FD SS B S	→	BS	SSQ
Exper. n = 8	BS	1	VC FD SS B S	→	2	VC FD SS B S	→	3	VC FD SS B S	→	4	VC FD SS B S	→	BS	SSQ RUQ

Note: IR— Instructor's Ratings; Evaluation Criteria consists of VC— Vehicle Control; FD— Following Distance; SS— Speed Selection; B— Braking; S— Shifting; Q— Questionnaires; SSQ— Simulator Sickness Questionnaire; RUQ— Realism, Usefulness Questionnaire; BS— Basic Skills Test.

Procedure

Prior to actual performance, experienced drivers will receive an orientation and familiarization drive in the simulator. They will need to become acclimated to the simulated driving environment and, in particular, to any function or control that has been modified from a truck (e.g., the mirrors are represented as screens) or that does not exist in the simulator. Afterwards, the experienced drivers will be screened for their susceptibility to simulation sickness by completing a questionnaire (see Appendix E). (Novice drivers will have been screened previously in the TOT (Part 1)). In addition, experienced drivers will be asked to fill out another questionnaire seeking information about their background and driving experience. If experienced drivers need to be recruited from commercial fleets, they will be tested prior to their shifts in order to manage the influence of fatigue. After the drivers have completed the orientation process, a general skills pre-test will be administered before the advanced portion of the study to establish some baseline information for differences between the groups. The pre-test will be conducted in the simulator. It will consist of a generic or composite scenario based on the scenarios developed for the PTDI units on Basic Operation and Safe Operating Practices of the TOT. The pre-test will consist of one trial for each unit for a total of eight trials. Scores from the pre-test will be collected in the form of instructor's observation for the number of pass/fail performances on each trial. Following the pre-test, all drivers will be tested individually for each of the four advanced scenarios. The four scenarios will be performed consecutively, but presentation of the scenarios will be randomized across drivers. Each scenario will be followed by a 10-minute break. After completing the four scenarios, all drivers will complete a post-test. Additionally, the experienced truck drivers only will complete a second post-experiment questionnaire (see Appendix B, Part 1).

Measures of Performance

Post-experiment Questionnaire. A Likert questionnaire consisting of about 35 items (5-point scale) (see Appendix , Part 2) will be administered to all eight (8) experienced drivers after they complete the scenarios and post-test. Twenty-six of these questions will be used to determine the degree of agreement among experienced truck drivers on issues related to the usefulness, realism, and similarity of the simulator versus a tractor-trailer. The opinion of experienced truck drivers coupled with driver performance data should provide support for determining the validity of simulation technology for advanced capabilities. Five (5) questions will provide qualitative data on the scenarios, while the remaining four (4) questions will provide information concerning driver experience, with actual driving events depicted in the scenarios and general driver experience.

Automated Data Collection. The recording of automated driver performance measures by the simulator will be triggered by the particular scenario and specific events (e.g., location, distance from objects, speed) in the visual database. In general, the performance measures may include (1) speed selection (i.e., percentage of time exceeding speed limit, speed variability), (2) fuel economy performance (i.e., gallons used, mpg), (3) braking performance (i.e., average/peak temperature), (4) number of crashes (including complete loss of vehicle/jackknife), (5) distance traveled in miles and tenths of miles, (6) travel time, (7) following distance (% time safe), (8) lane position (% left, center, right), (9) shifting performance (% at, below, above RPM; total number of shifts, grinds, and engine stalls), and (10) number of critical incidents (e.g., run off the road).

Expert Ratings. Two qualified instructors will observe the driver's performance from the bird's-eye-view instructor station. From this vantage point, the instructors will not be aware of who is driving the truck, while providing evaluations exclusively on the driver's performance. They will use a 5-point Likert scale for rating driver efficiency and safety for vehicle control, following distance, speed selection, braking, shifting, and risk taking (see Appendix B).

CHAPTER VI
DATA ANALYSES

The following paragraphs propose a strategy for evaluating the data collected through this validation effort. However, the nature of field investigations is such that there may be modifications in the design because of issues identified during the pilot studies or other unforeseen events. Therefore, the following analyses are only offered as provisional and are based on the design as identified in this report.

Forward Transfer of Training (Parts 1 and 3)

Training Effectiveness

Two of the proposed criterion measures of performance on the training curriculum were number of training trials and time to reach instructional objectives. These data will be submitted to multivariate analyses of variance (MANOVAs), with phase as a repeated measures variable.

The three-way MANOVA will support the observations (means and standard deviations) by showing main effects of training condition and training phase with Wilks's exact F test. Any significant interaction should be examined further by simple main effects. Planned comparisons for differences between simulation-based training versus conventional training and between the respective simulation-based training groups should be carried out.

Training Transfer

Differences between training methods for performances on the Pre-Street Range Test (PSRT) and the Final Examination Road Test (FERT) will be determined by submitting total correct number of items and total time to complete the truck-based tests to a MANOVA. Total correct number of items on the road test for the Commercial Drivers License (CDL) will be submitted to a separate ANOVA. Proportion of variance accounted for by training method can be determined either by an analysis of variance approach (eta squared , η^2) or by a regression approach. Regression analysis will provide regression coefficients for predicting the effect of training method on outcome performances for the PSRT, FERT, and the CDL.

Testing

Regression analysis will provide correlation coefficients for relating the test scores and test time to job performance measures.

Differences between the truck and the simulation-based version of the PSRT and the FERT will be determined by submitting the total correct number of items and the total time to complete the test to a MANOVA. Pearson-product moment correlation for the relationship between performance outcomes of the simulation-based versions of the PSRT and the FERT will be calculated and compared to the truck-based version of the PSRT and FERT.

Job Performance

Differences between training methods for job performance will be determined by submitting number of accidents, number of citations, number of points on driving record, and supervisory ratings from 3-month and 12-month evaluations to a MANOVA. Proportion of variance accounted for by training method can be determined by either an analysis of variance approach or by a regression approach. Regression analysis will provide regression coefficients for predicting the effect of training method on subsequent performance on the job.

Advanced Capabilities (Part 2)

Post-experiment Questionnaire (Appendix B, Part 1)

Questions 1-4 address truck driver experience. A composite score representing overall experience level should be computed through assignment of points to responses. A point-per-unit response is proposed to permit a range of scores. This score will be used as a covariate in the analysis of driver performance data.

Questions 5-30 address experienced truck drivers' perceptions of realism, usefulness, and similarity for the scenarios. Because multiple raters will be applying multiple ratings, Kendall's Concordance (W) test statistic is suggested to compute inter-rater agreement across the questions.

Questions 31-35 address experienced truck drivers' opinion concerning scenario content. Descriptive statistics and summary are appropriate.

Automated Data Collection (Driver performance data)

A 2 (Skill group: Experienced vs. Novice) x 4 (Scenario: Emergency Maneuvers vs. Special Rigs vs. Speed Management vs. Extreme Driving Conditions) MANOVA with the score from the pre-test as a second covariate should be performed to support observations of mean and standard deviations of driver performance data. Main effects and interactions should be calculated using Hotelling's T^2. Any significant interactions should be examined further by tests of simple main effects. Differences in pre-test and post-test scores should be examined through analysis of variance.

Instructor's Rating Scale (Appendix B, Part 2)

The comparison of novice versus experienced driver performance data rests with the assumption that experienced drivers will perform better than novices. In this regard, the experienced drivers should provide some normative information concerning basic performance for advanced capabilities skills. However, although experienced truck drivers will have numerous years of on-the-road driving, there exists the possibility that one or more may not have encountered the driving situations of the scenarios under actual conditions. Consequently, their driving performances may not be reliably different from those of the novice truck drivers.

For this reason, the instructor's rating scale will provide assessment of differences between the two groups not captured by the performance data of the driving scenarios. It asks for "expert" ratings of driver performance for efficiency and safety on five (5) areas (vehicle control, following distance, speed selection, braking, and shifting) relevant to each of the scenarios.

The first step is to establish inter-rater agreement between the ratings of the five areas for each of the scenarios. The Kappa statistic should be appropriate, provided the data is not highly skewed. An alternative statistic may be the intraclass coefficient. Kappa should be calculated for each of the areas across scenarios for mean safety and efficiency rating. For Kappa, a 75% agreement between raters is generally considered excellent.

Chi-square analysis of experienced drivers versus novice drivers for mean efficiency and safety ratings for each of the dimensions would help to establish if a relationship exists between experience level and ratings for vehicle control, following distance, speed selection, braking, and shifting. At this point, correlating mean efficiency and safety ratings for each of the scenarios with driver performance data, specifically, run time and combined number of accidents and incidents, respectively, should provide partial evidence for simulation in screening specific advanced capabilities.

Cost-Benefit Analysis

Although a calculation of cost-benefit cannot be determined until the actual validation is conducted, information on acquisition and maintenance costs of various simulators were addressed in *Commercial motor vehicle simulation technology to improve driver training, testing and licensing methods: Final report* (DOT Publications No. FHWA-MC-96-003) and will again be reviewed as part of the validation experiment.

APPENDIX A

BEHIND-THE-WHEEL DRIVING TRAINING SCENARIOS

The training scenarios presented in the following pages are intended to structure the learning activities during the simulation-based, behind-the-wheel (BTW) training. Section A.1 contains the driving scenario descriptions for the units on Basic Operation and Safe Operating Practices included as part of the Forward Transfer of Training. Some scenarios depict situations in which implementing the scenario using a truck would be difficult or unsafe. These situations include weather changes on demand, road hazards, and truck system failures, from engine loss of power to tire blowouts. Because these system degradations cannot be safely and repeatedly produced in real vehicles for training purposes, they are included in the Advanced Capabilities scenarios (section A.2) to demonstrate and showcase the driving simulator capabilities.

The simulation-based training scenarios have been carefully scripted from information (including training time) provided in the Federal Highway Administration/Professional Truck Drivers Institute of America (FHWA/PTDIA) Model Curriculum. They are also based on peer review input (for content). They are intended for use in standardized training for novice drivers preparing for the CDL.

Notes: ***1 Times allocated are precise (e.g., 3 minutes for specific exercise), but the instructor may wish to round up or down, as appropriate.***

2 Where practical, diagrams, references, and other supporting materials and referenced training information from FHWA Model Curriculum for Training Tractor-Trailer Drivers has been included to create a stand-alone document for ready reference.

3 Capabilities of the simulator selected as a test bed will dictate exactly which of these scenarios can be used in the course of the experiment.

4 Students or drivers will need to reference FHWA/PTDI Model Curriculum for specifics on other non-BTW scenarios.

A.1 FORWARD TRANSFER OF TRAINING

Unit 1.4 MASTER BASIC CONTROL

Purpose
The purpose of this unit is to provide the student with proper procedures in the basic startup and shutdown procedure, and in basic vehicle control.

Task Objectives
1. Start up, warm up, shut down.
2. Move vehicle forward and backward.
3. Stop vehicle smoothly.
4. Back up in straight line.
5. Position the vehicle for turns and negotiate turns.

Instruction
A demonstration and practice in start up and shut down will take place in the simulator and will be followed by a demonstration and practice in the basics of vehicle control. The simulator practice will be complemented by range practice in one or more trucks that will provide the actual look and feel of engine warm up. In the simulator, the driver will start the vehicle, test the trailer hookup, and then move off slowly for about 100 feet and stop smoothly. He or she will repeat this exercise three times and then back the vehicle in a straight line to the original starting point. The student will maneuver through the geometric figures described on the following pages and drive around corners of various radii at slow speeds until judged competent by the instructor. The student will back the vehicle into a box of standard lane width. He or she will practice each of these activities until the instructor is confident mastery is achieved. The simulator practice will precede the corresponding driving range practice in each part of this unit.

PTDI Hours of Instruction

Student hours of instruction are based on the PTDI curriculum. The following table reflects the requirements for the unit.

Student Hours: Required Instruction Only

Unit	Basic Operation	Classroom	Lab	Range	Street
1.4	Basic Control	0.75	0	2.25	0

The BTW time in the following table reflects the hours of instruction for the Range requirements from the PTDI curriculum. The time is distributed between the respective simulation-based training and truck-based training groups.

***Simulator & Truck Time BTW Allocations*—Range**

	Conventional		Experimental	
Activity	Sim	Truck	Sim	Truck
	Hr min	Hr min	Hr min	Hr min
Starting, Warming Up & Shutting Down	0:00	0:10	0:07	0:03
Putting the Vehicle In Motion	0:00	0:30	0:20	0:10
Turning the Vehicle	0:00	1:35	0:65	0:30
Total Hours	*0:00*	*2:15*	*1:32*	*0:43*

NOTE. The preceding table addresses BTW training only. Drivers and students need to reference Model/PTDI curriculum for classroom requirements for this unit.

Scenario Description

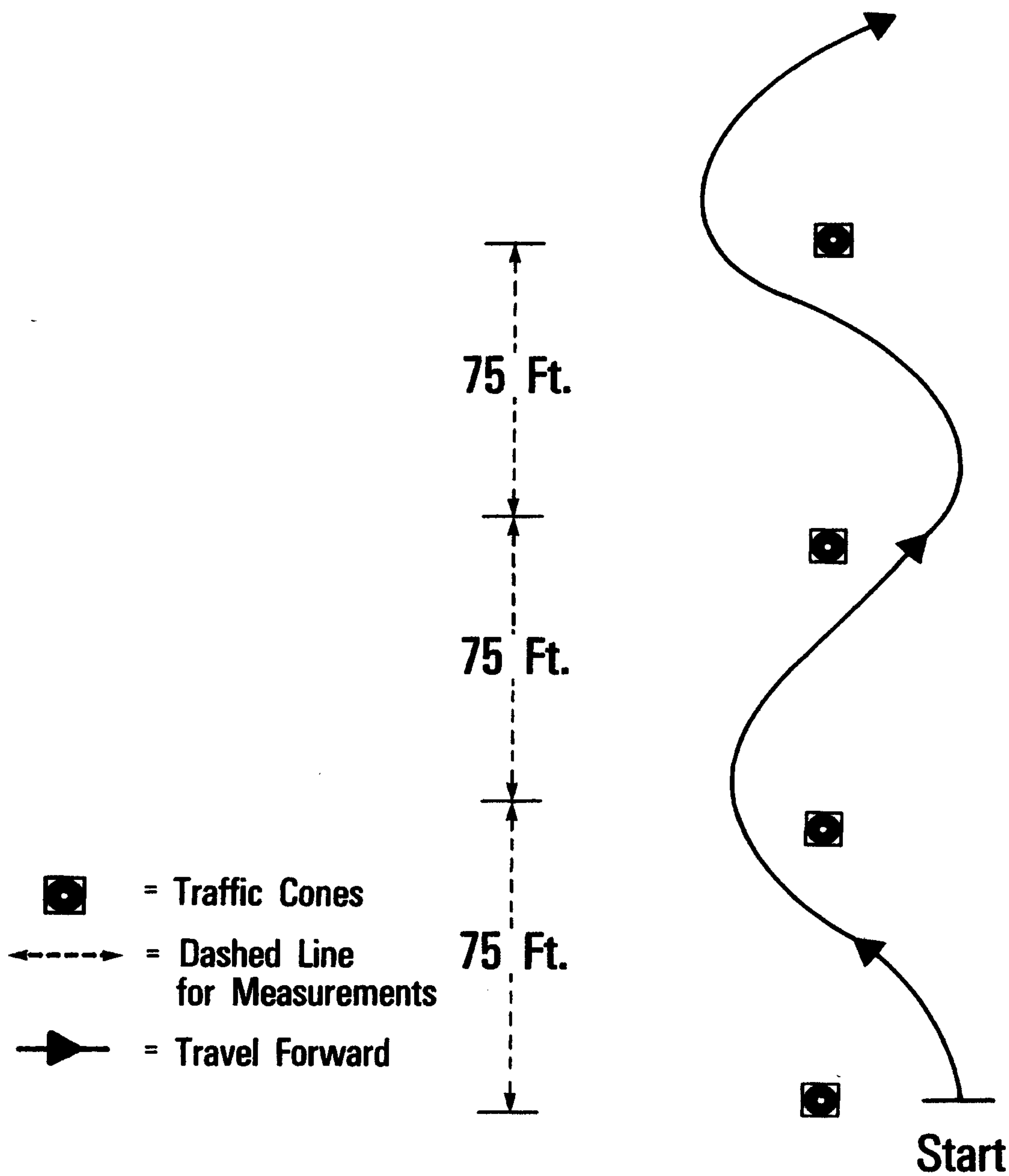
The simulator cab will have forward out-of-window displays covering 180 degrees horizontally, and left and right rear-vision displays for plane and convex mirror views. A birds-eye display will be provided at the instructor station for other students to watch the student driver. This scenario will consist of three distinct segments. During the startup-shutdown segment, the truck cab will provide realistic controls, displays, and system responses to mimic warmup behavior for at least one type of four-cycle engine. For the trailer hookup and start off segment, the truck cab will have a functional trailer brake. The vehicle will have various loads for start-stop practice. At least 300 feet of pylon demarcated 25-ft wide lane is required for this exercise to permit 3,100 foot long start-stop exercises. In the turning segment, a driving range is required that is sufficiently large to allow complicated tractor-trailer maneuvers. It should have lane markers painted on it for turns of various radii and for straight line backing. Initially, the lane demarcation can be made with cones that fall over when struck by the vehicle, while more advanced practice may use lines and markings on the road surface. Seven general types of turns are required. The serpentine turn is defined in Range Diagram—Exercise 2 of Unit 1.4; the figure 8 turn is defined in Range Diagram—Exercise 3, and the restricted figure 8 is defined in Range Diagram—Exercise 4. The remaining turns are all variations on figure 8's and are defined in Range Diagram

—Exercise 5 through Range Diagram—Exercise 8. No special background scenery is required. The vehicle model in all scenarios will be capable of a 300 lb/HP performance under normal load.

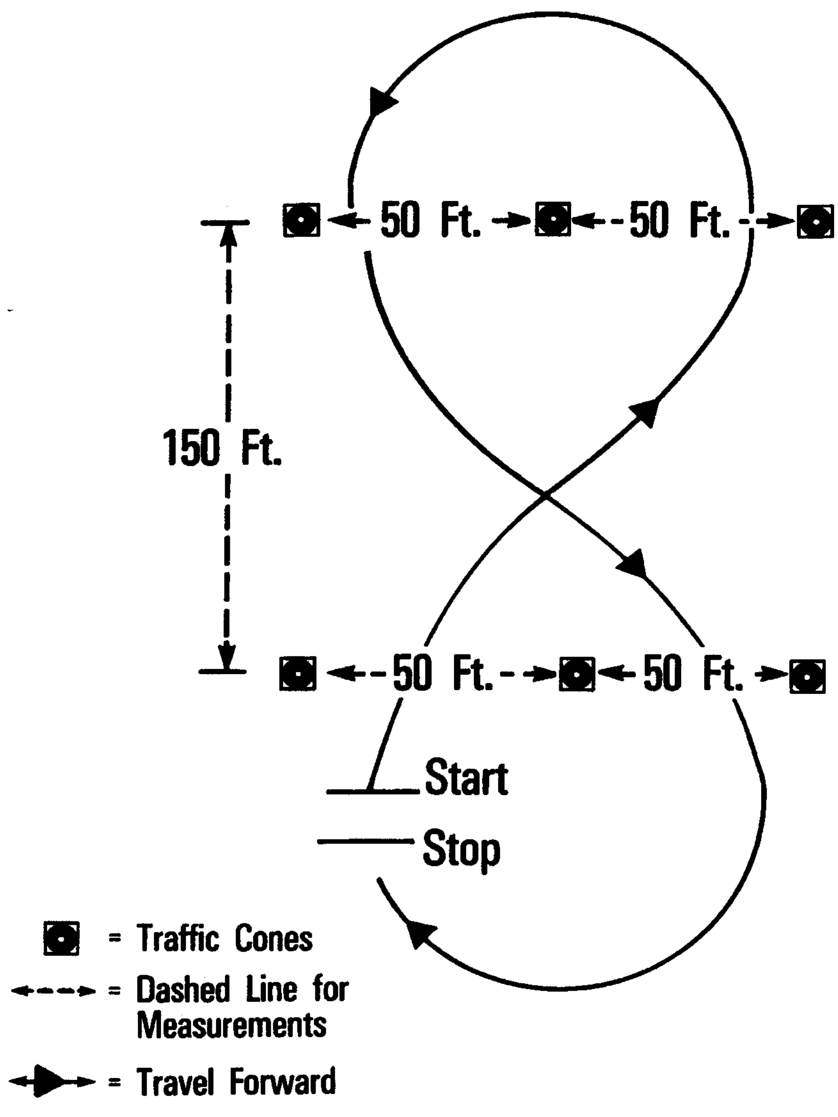
Parameters

Time of day	Daylight
Weather	Clear
Traction	Dry
Terrain	Flat
Distances	N/A
Road type	Driving range
Traffic control devices & signs	No
Other traffic	No
ITS aids	No
Hazards	No

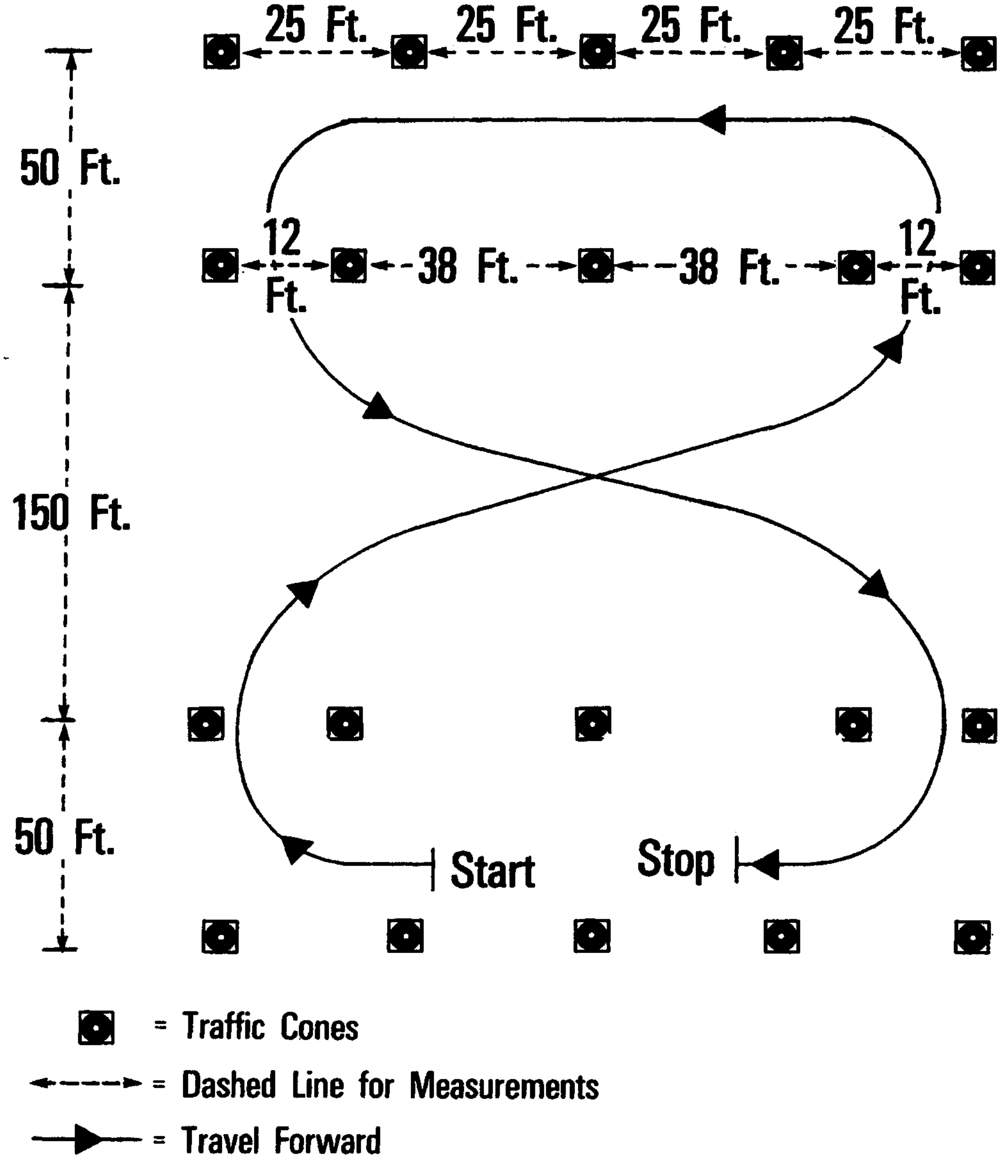
Range Diagram—Exercise 2
(Serpentine)



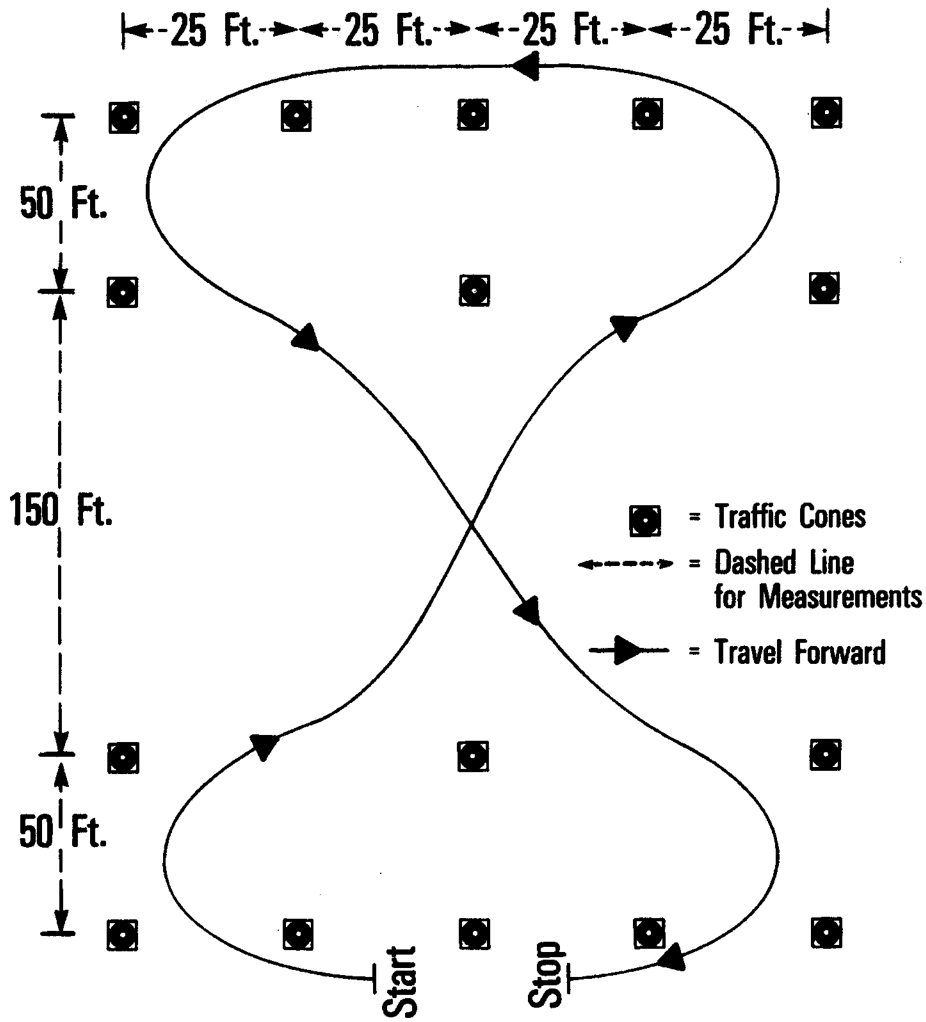
Range Diagram–Exercise 3
(Figure 8)



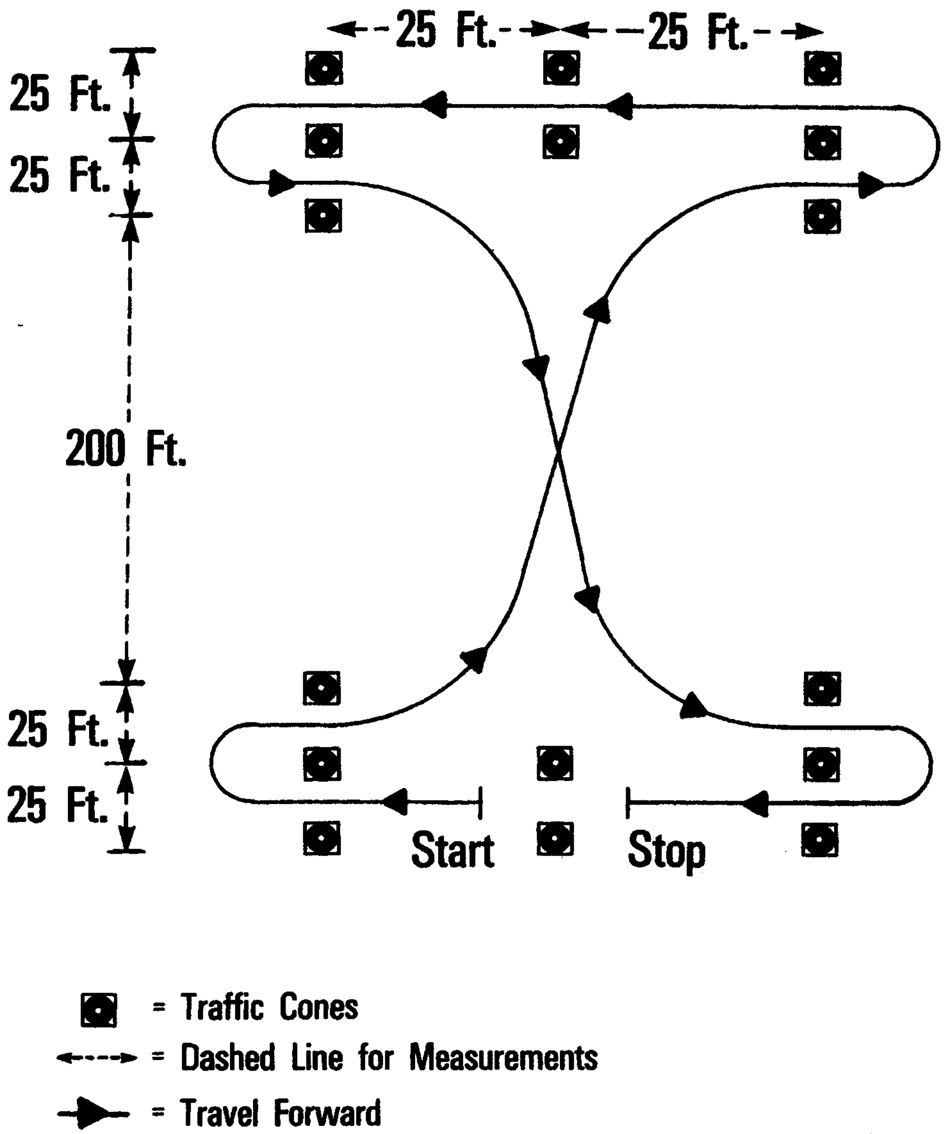
Range Diagram–Exercise 4
(Restricted Figure 8)



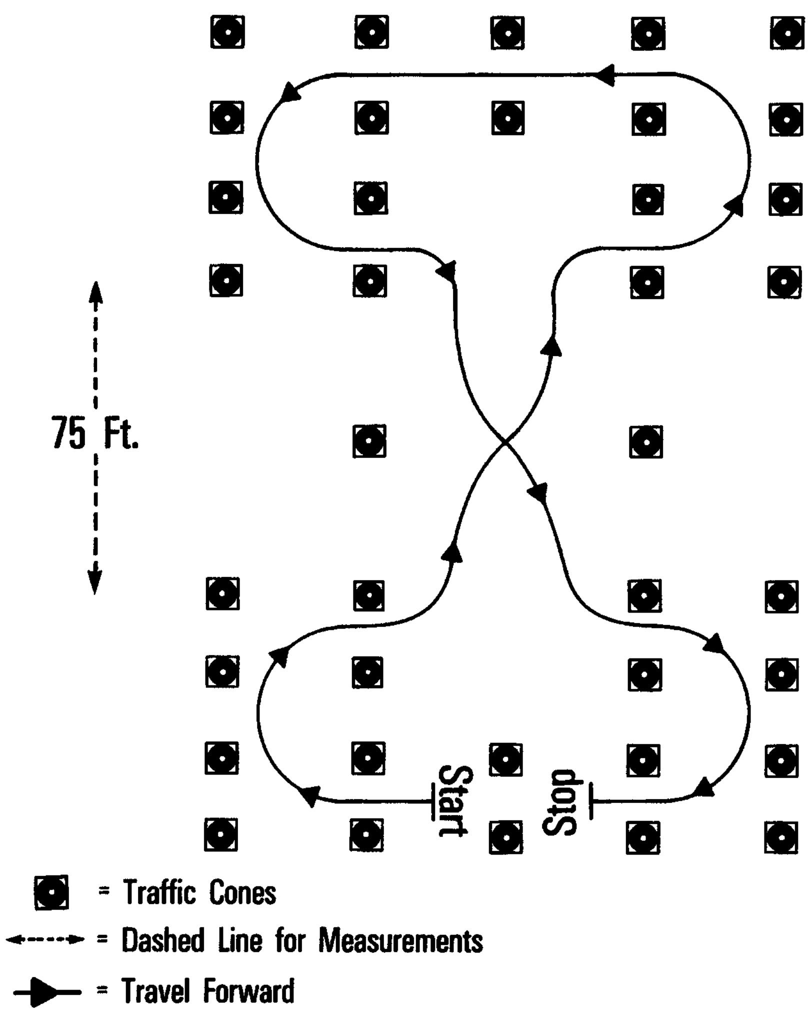
Range Diagram–Exercise 5
(Turns)



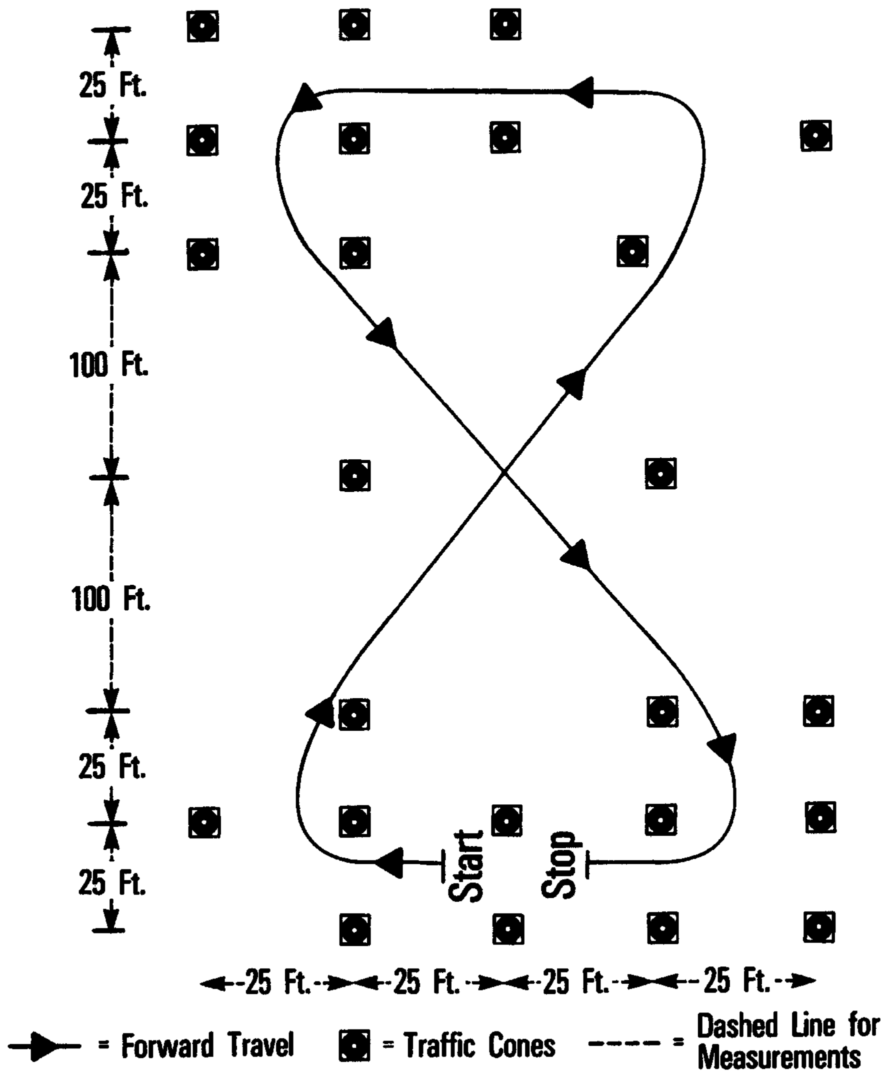
Range Diagram—Exercise 6
(Restricted Turns)



Range Diagram—Exercise 7
(Sharp Turns)



Range Diagram—Exercise 8
(Combination Turns)



Parameters

Time of day	Daylight
Weather	Clear
Traction	Dry
Terrain	Mostly rural flat;some gently rolling hills
Distances	Point-to-point 20 miles
Road type	City streets and rural two-lane roadway
Traffic control devices & signs	Stop signs and/or traffic lights
Other traffic	Slower lead vehicle may be used at certain times on highway, plus other light traffic in urban part of scenario.
ITS aids	No
Hazards	No

Unit 1.6 BACKING

Purpose

The purpose of this unit is to provide the student with an understanding of the principles of backing an articulated vehicle and to provide practice in backing. The student driver will learn to back up a combination vehicle along various curves and into complex geometrical spaces as is required in many real loading docks.

Task Objectives

1. Back in a straight line and along a curved path.
2. Back into an alley dock.
3. Parallel park.
4. Park in a jackknife position.
5. Judge side, rear, and overhead clearances and path of trailer.

Instruction

Initial demonstrations of backing will be done with an instructor in the simulator cab so that students can see a bird's-eye-view of the activity done correctly. Similarly, the students working in groups of two or three will observe each other's attempts from the overhead view. Skill development will take place in initial and advanced practice sessions.

PTDI Hours of Instruction

Student hours of instruction are based on the PTDI curriculum. The following table reflects the requirements for the unit.

Student Hours: Required Instruction Only

Unit	Basic Operation	Classroom	Lab	Range	Street
1.6	Backing	0.75	0	7.00[1]	0

The BTW time in the following table reflects hours of instruction for Range requirements. The time is distributed between the respective simulation-based training and truck-based training groups.

***Simulator & Truck Time BTW Allocations*—Range**

	Conventional		Experimental	
Activity	Sim	Truck	Sim	Truck
	Hr min	Hr min	Hr min	Hr min
Alley dock sight	0:00	2:20	1:40	0:40
Jackknife park sight side	0:00	2:20	1:40	0:40
Parallel parking	0:00	2:20	1:40	0:40
Total Hours	*0:00*	*7:00*	*5:00*	*2:00*

[1] This is the longest duration unit in the PTDI tractor-trailer driver curriculum.

Note. The preceding table addresses BTW training only. Drivers and students need to reference Model/PTDI curriculum for classroom requirements for this unit.

Scenario Description

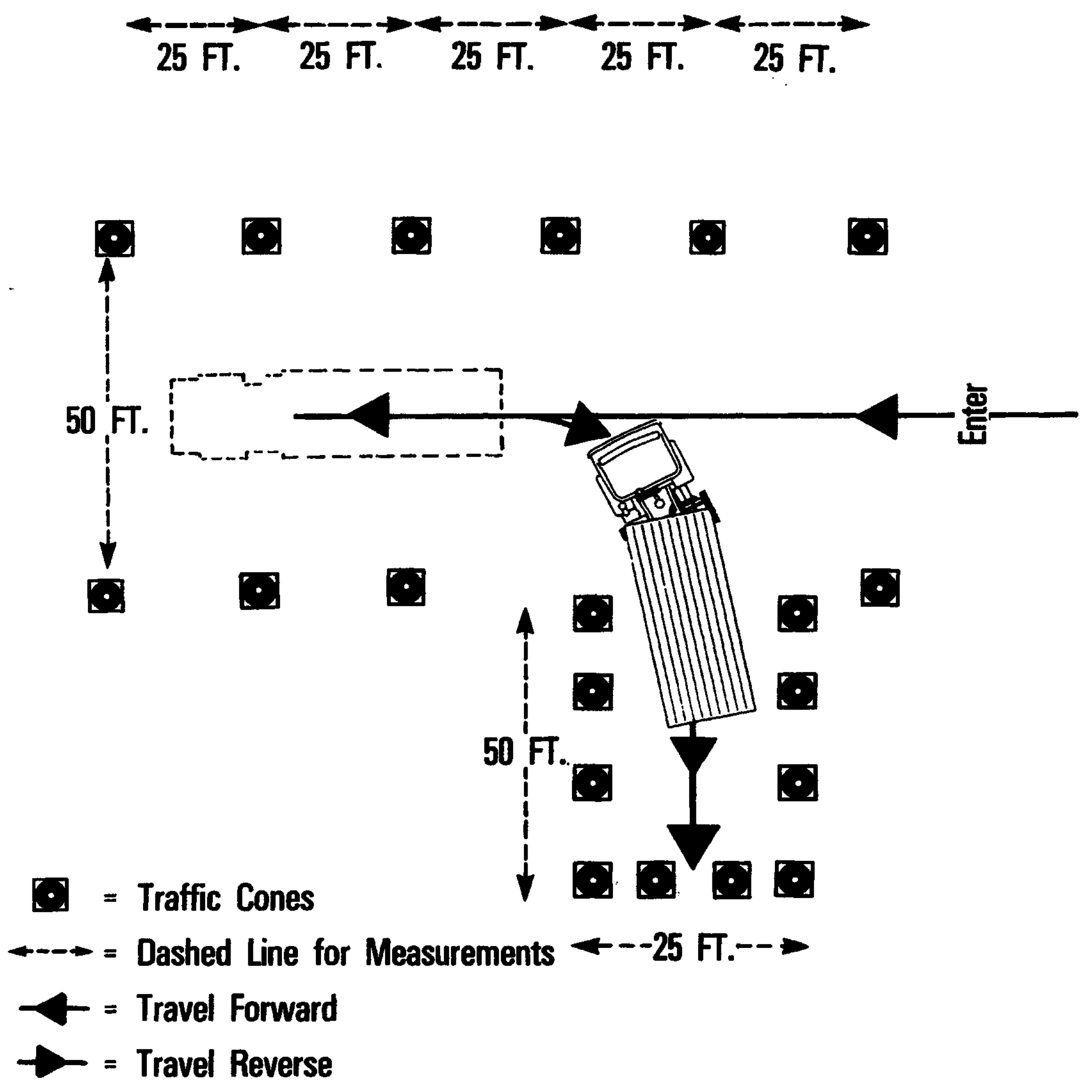
This scenario requires a number of segments for each backing situation. The Model Curriculum Unit 1.6 Range Diagram Exercises 1, 2, and 3 provide guidance for the geometry defining alley dock parking, jackknife parking, and parallel parking. Street widths should be 50 feet and alley widths 25 feet according to Range Diagram-Exercise 1 of Unit 1.6. These widths may be tightened during the practice sessions. For the parallel parking exercise the space should be 75 feet for a single-axle trailer or 1.36 times the rig combination length for longer combinations, or vehicle length plus 15 to 20 feet. The basic and advanced practice sessions will use different scenario details. For the basic practice sessions a driving range that is sufficiently large to allow complicated tractor-trailer maneuvers is required. It should have lane markers painted on it for turns of various radii and for straight line backing. The lane markers will be supplemented with cones that fall over when struck by the vehicle. A bird's-eye-view display will be provided to replay backing up attempts by student drivers and enable other students to observe from above and to clearly see the results of various driver steering inputs. For the advanced sessions building walls will be used in lieu of cone markers to provide realistic segments and to reduce the driver's preview distance. Pedestrians or other hazards shall be available for insertion into advanced sessions at the instructor's discretion. The hazards will be made to appear from behind objects or to disappear into the driver's blind spots.

Parameters

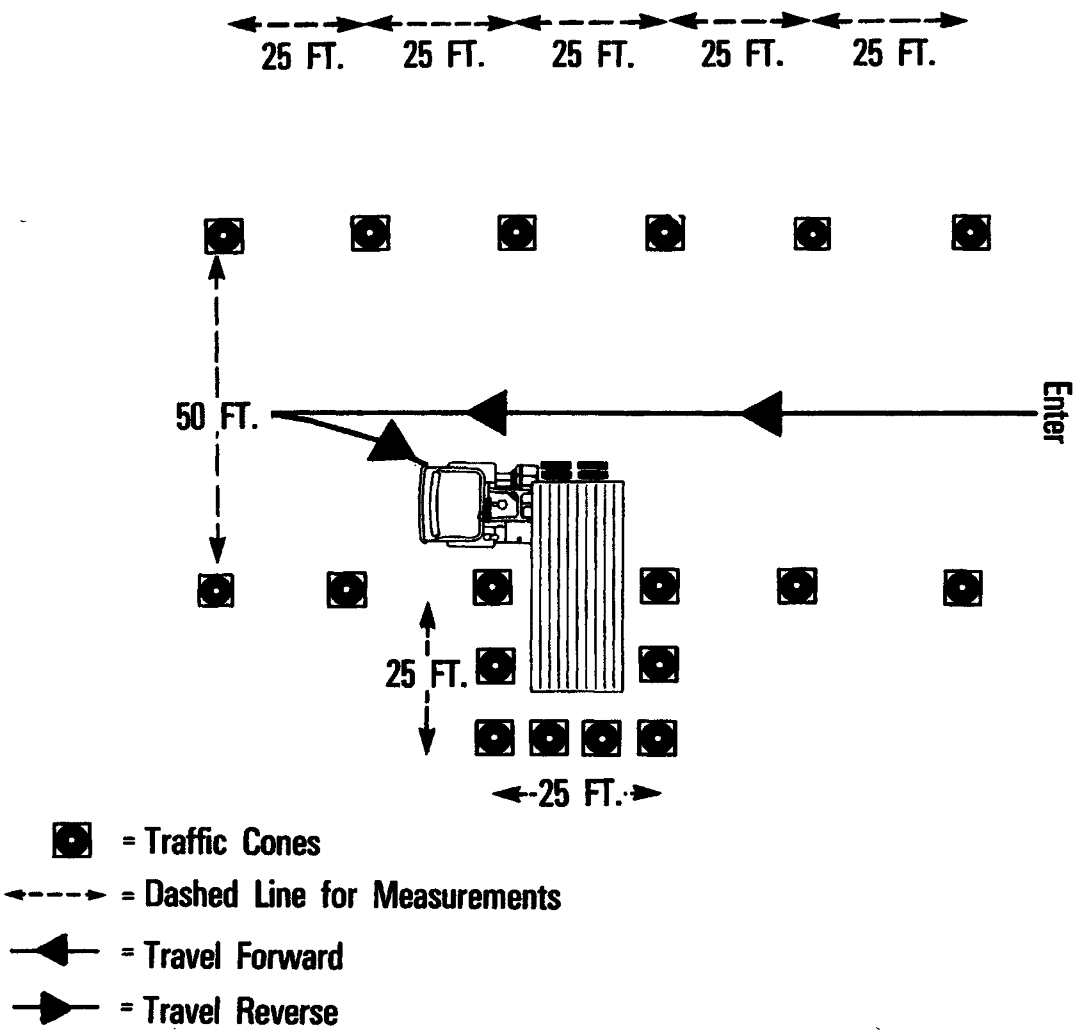
Time of day	Daylight
Weather	Clear
Traction	Dry
Terrain	Flat
Distances	N/A
Road type	Driving range
Traffic control devices & Signs	N/A
Other traffic	N/A
ITS Aids	N/A
Hazards	N/A

Range Diagram—Exercise 1

Alley Dock

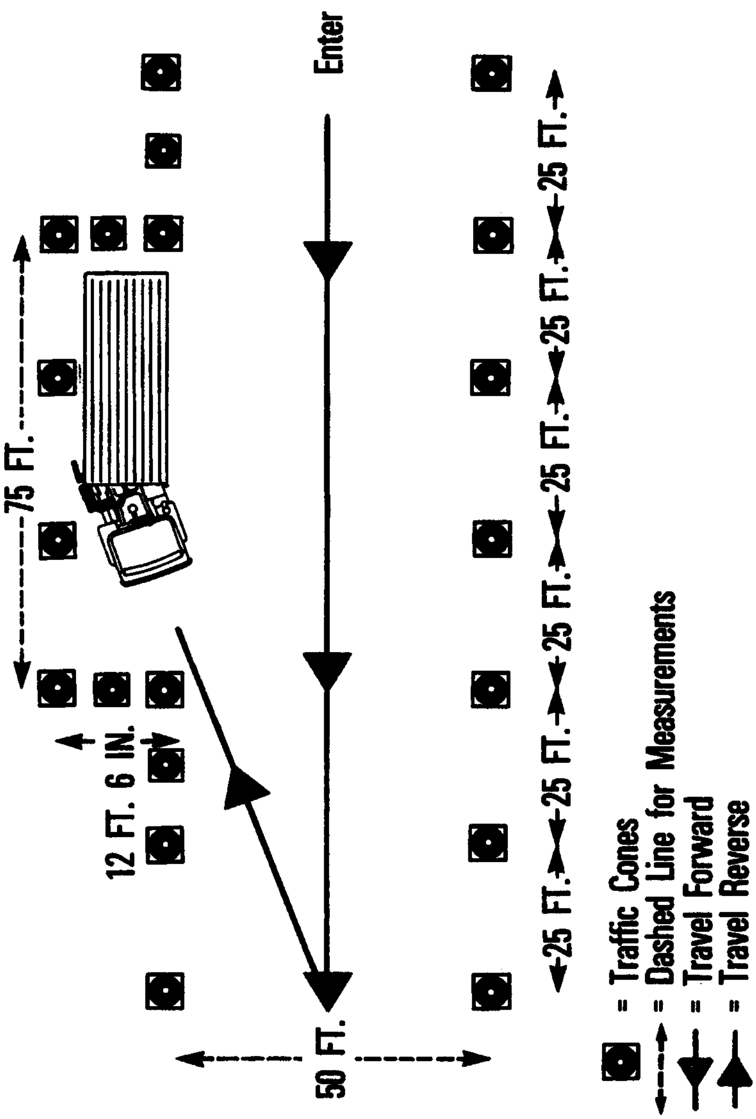


Range Diagram—Exercise 2
Jackknife Park



Range Diagram—Exercise 3

Parallel Park



Unit 1.7 COUPLING AND UNCOUPLING

Purpose

The purpose of this unit is to provide the student with practice in the simulator, and later in a truck, backing the tractor onto the trailer.

Task Objectives

1. Align the tractor properly to connect with the trailer.
2. Secure the trailer against movement.
3. Back the tractor onto the trailer kingpin without damage.

Instruction

The student will be required to back up to and couple with a trailer parked in a driving range and later uncouple the trailer. Many of the key tasks in this unit, such as coupling and uncoupling hoses between the tractor and trailer and setting up the landing gear, take place outside the cab, so they are not suited for a typical driving simulator. However, the simulator can still play a useful role. The primary emphasis in the simulator session will be on aligning the truck and backing it in before coupling. A number of repetitions from a straight backup approach will be practiced to give the student driver an understanding of the proper visual cues to be used.

The student will already have been exposed to the fifth wheel coupling mechanism during Unit 1.3, Vehicle Inspections. Therefore, the simulator session will precede the range sessions in this unit.

PTDI Hours of Instruction

Student hours of instruction are based on the PTDI curriculum. The following table reflects the requirements for the unit.

Student Hours: Required Instruction Only

Unit	Basic Operation	Classroom	Lab	Range	Street
1.7	Coupling & Uncoupling	0.75	0	1.00	0

The BTW time in the following table reflects the hours of instruction for Range requirements from the PTDI curriculum. The time is distributed between the respective simulation-based training and truck-based groups.

***Simulator & Truck Time BTW Allocations* - Range**

	Conventional		Experimental	
Activity	Sim	Truck	Sim	Truck
	Hr min	Hr min	Hr min	Hr min
Coupling & Uncoupling	0:00	1:00	0:40	0:20
Total Hours	*0:00*	*1:00*	*0:40*	*0:20*

NOTE: The preceding table addresses BTW training only. Drivers and students need to reference the Model/PTDI curriculum for classroom requirements for this unit.

Scenario Description

A driving range width that is sufficiently large to allow a tractor to back onto a trailer from different angles is required. It should have lane markers or cones that fall over when struck by the vehicle to guide the driver during the early practice in making the required different radii turns; these guides will be removed for later practice. Different types of trailers will be provided, including flatbeds and box trailers to demonstrate the various visual cues the driver must use for alignment. No special background scenery is required, although other trailers may be provided to give the appearance of a trailer park and to obscure loading docks.

Parameters

Time of day	Daylight
Weather	Clear
Traction	Dry
Terrain	Flat
Distances	N/A
Road type	Driving range
Traffic control devices & signs	N/A
Other traffic	Optional stationary trailers
ITS aids	No
Hazards	No

Unit 1.8 PROFICIENCY DEVELOPMENT

Purpose

The purpose of this unit is to tie together skills that have been practiced separately in the four previous BTW units of Basic Operation of the Model Curriculum. It prepares the student for street driving exercises in Safe Operating Practices. The general approach adopted for this unit is to iterate the simulator practice with range practice, and then iterate the simulator practice with street practice.

This unit prepares the student for the Pre-Street Range Test (PSRT) that is required before the student progresses to street driving. It also prepares the student driver for the driving range part of the Final Examination Road Test (FERT) taken at the end of the course. The test requirements for the PSRT are outlined in Appendix D. The driving range exercises will escalate through three levels of difficulty as the room to maneuver dimensions are reduced. The exercises also have time limits for each level of difficulty. Exercise dimensions and times are provided in the Model Curriculum. The student will perform the exercises for task objectives 1 to 6 in the simulator, using the novice-level clearance dimensions, and will then perform these exercises on the range and take the Pre-Street Range Test. The exercises will then alternate between the simulator and range using the intermediate level clearances, and finally, the advanced-level clearances. The latter will be used for the driving range Final Examination Test Battery. Those students passing the Pre-Street Range Test will move on to the street portion of this unit.

Street driving is undertaken with two levels of difficulty: a low traffic density environment and a moderate traffic density environment. Before taking the street run, students will drive a similar simulator run. They will then take the low traffic density street run and alternate with simulator runs as difficulty is increased by adding traffic on the simulator runs.

Task Objectives

1. Maneuver forward and backward through sharp turns.
2. Maneuver through a series of sharp turns in both directions.
3. Maneuver into areas restricted to the rear, side, and front.
4. Parallel park.
5. Judge the position of the right wheel.
6. Judge clearances at the rear, front, sides, and overhead.
7. Maintain proper vehicle and engine speed on upgrades and downgrades.

PTDI Hours of Instruction

Student hours of instruction are based on the PTDI curriculum. The following table reflects the requirements for the unit.

Student Hours: Required Instruction Only

Unit	Basic Operation	Classroom	Lab	Range	Street
1.8	Proficiency Development	1.50	0	10.00	6.00

The BTW time in the following table reflects the hours of instruction for Range & Street requirements from the PTDI curriculum. The time is distributed between the respective simulation-based training and truck-based groups.

***Simulator & Truck Time BTW Allocations* - Range & Street**

	Conventional		Experimental	
Activity	Sim	Truck	Sim	Truck
	Hr min	Hr min	Hr min	Hr min
Novice	0:00	3:20	2:15	1:05
Intermediate	0:00	3:20	2:15	1:05
Advanced	0:00	3:20	2:15	1:05
Street	0:00	6:00	4:00	2:00
Total Hours	*0:00*	*16:00*	*10:45*	*5:15*

NOTE: The preceding table addresses BTW training only. Drivers and students need to reference Model/PTDI curriculum for classroom requirements for this unit.

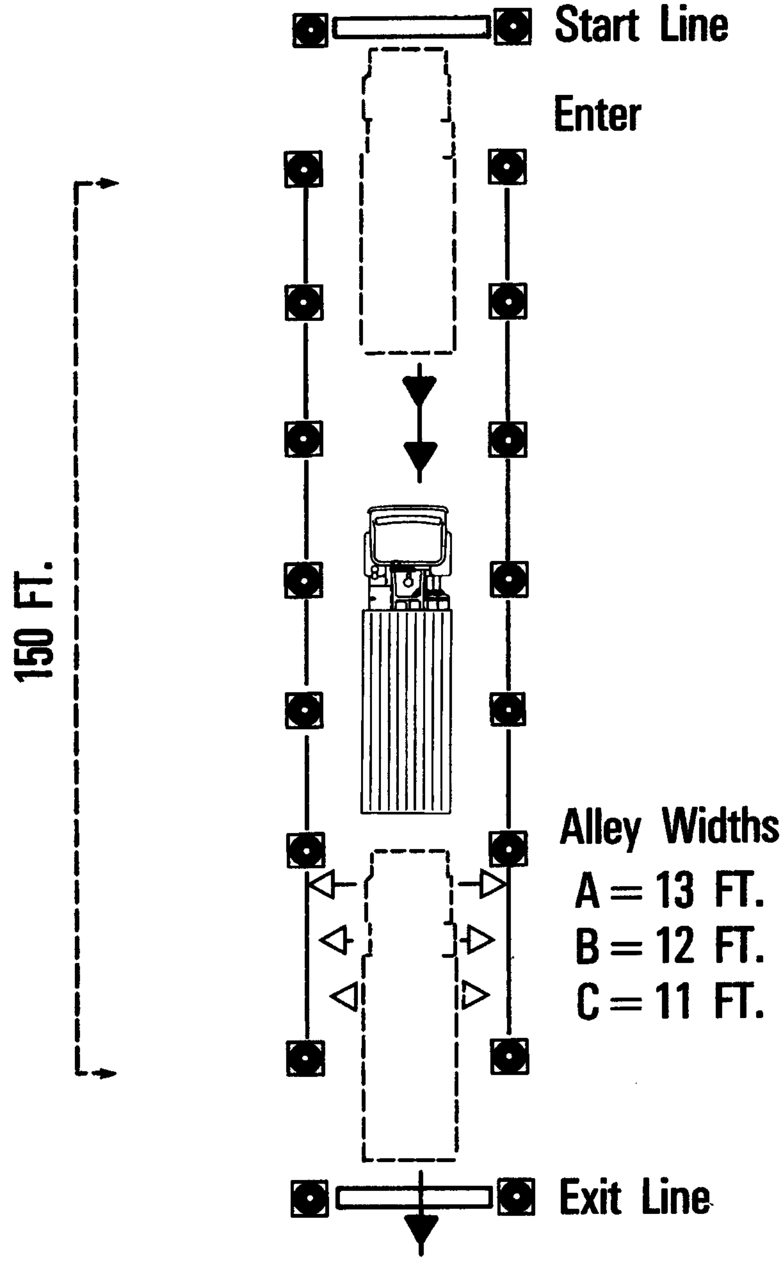
Scenario Description

Two types of scenarios are required for this unit; a set of driving range scenarios and a street (urban and rural) scenario. The driving range scenarios will be defined by the configurations described in Unit 1-8 diagrams, Range Diagram-Exercise 1 to Range Diagram-Exercise 6 and Range Diagram-Exercise 8. These diagrams describe the following set ups: straight line backing, offset alley backing, alley dock backing, jackknifed alley dock backing, serpentine forward and reverse, jackknifed parallel parking, and overhead clearance. Each configuration has dimensions for each of three levels of difficulty. Pylons and pavement markings will set up for the two less demanding difficulty levels, and a more realistic alleyway and loading dock arrangement will be set up for the most difficult level. The street scenario will be based on Unit 1.5. Two traffic density levels will be provided; one very light traffic and the other moderate traffic.

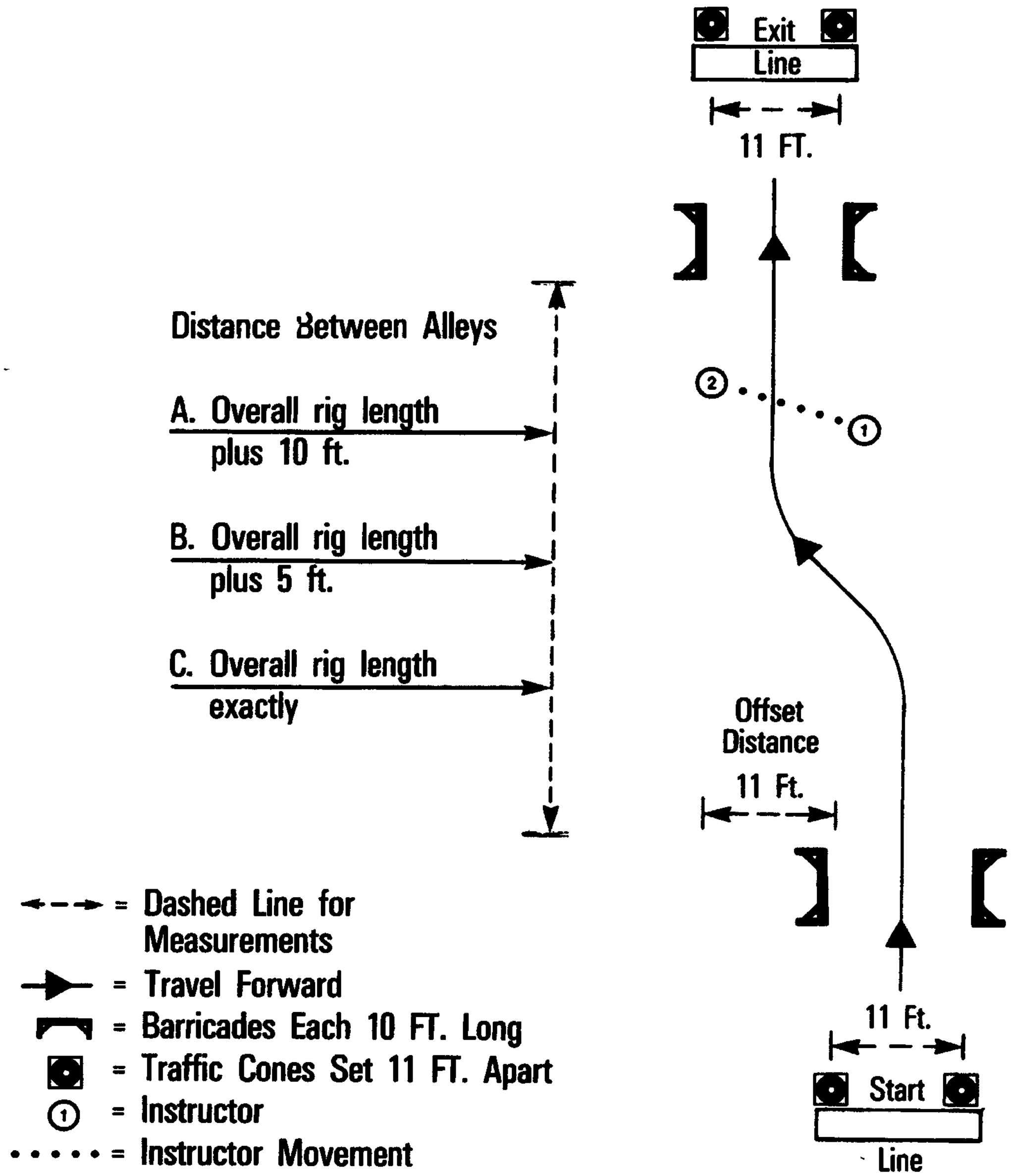
Parameters

Time of day	Daylight
Weather	Clear
Traction	Dry
Terrain	Driving range and hilly route
Distances	20 miles
Road type	Urban and rural two- and four-lane roadways
Traffic control devices & signs	Stoplights, and signage
Other traffic	Light and moderate
ITS aids	No
Hazards	No

Straight Line Backing

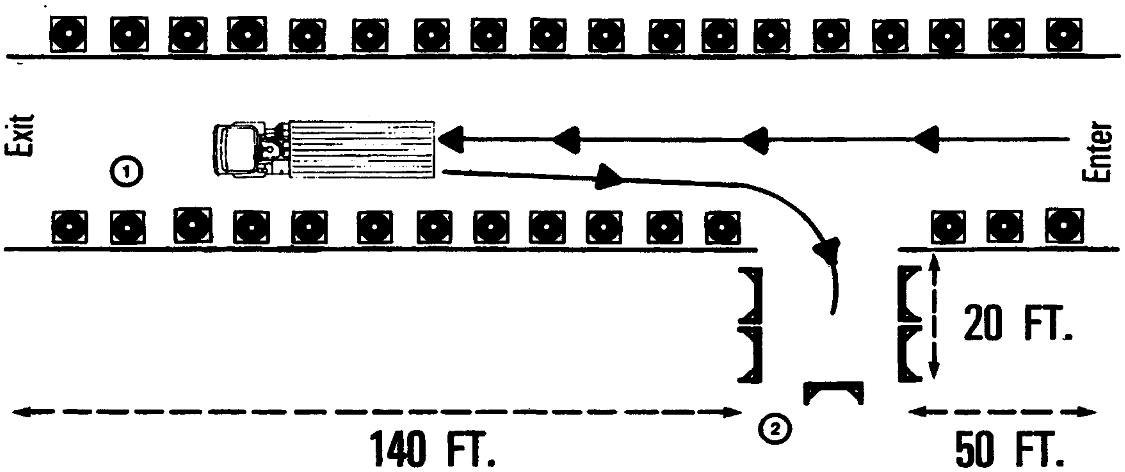


Range Diagram
Exercise 2–Offset Alley



Range Diagram
Exercise 3–Alley Dock

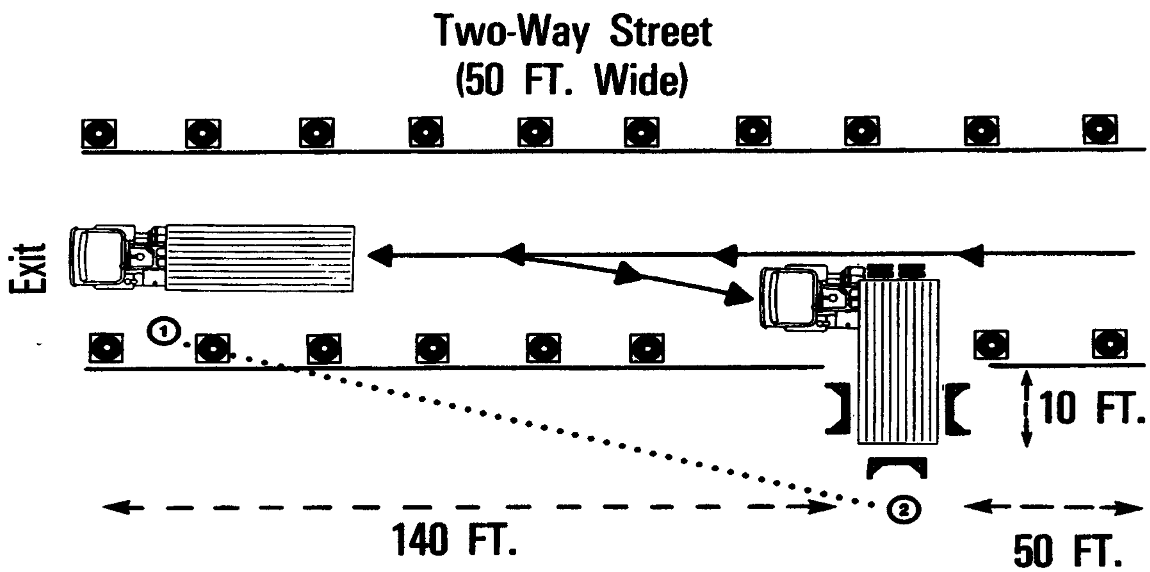
Two-Way Street
(50 FT. Wide)



Dock Widths
A=12 FT., 10 IN.
B=12 FT., 3 IN.
C=11 FT., 8 IN.

= Travel Forward
=Barricades (4) Each 10 FT Long
=Traffic Cones Set 10 FT. Apart
=Instructor Position
=Instructor Movement
= Dashed Line for Measurements

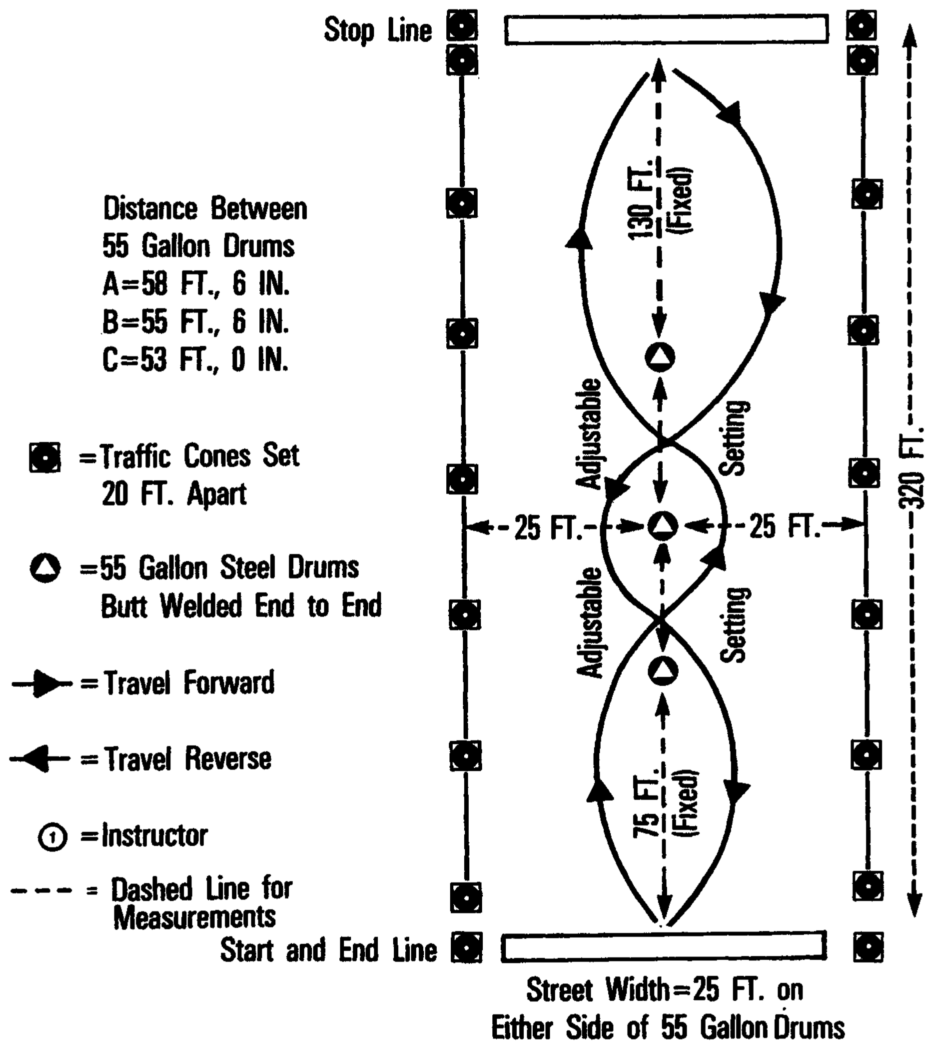
Range Diagram
Exercise 4–Alley Dock–Jackknifed



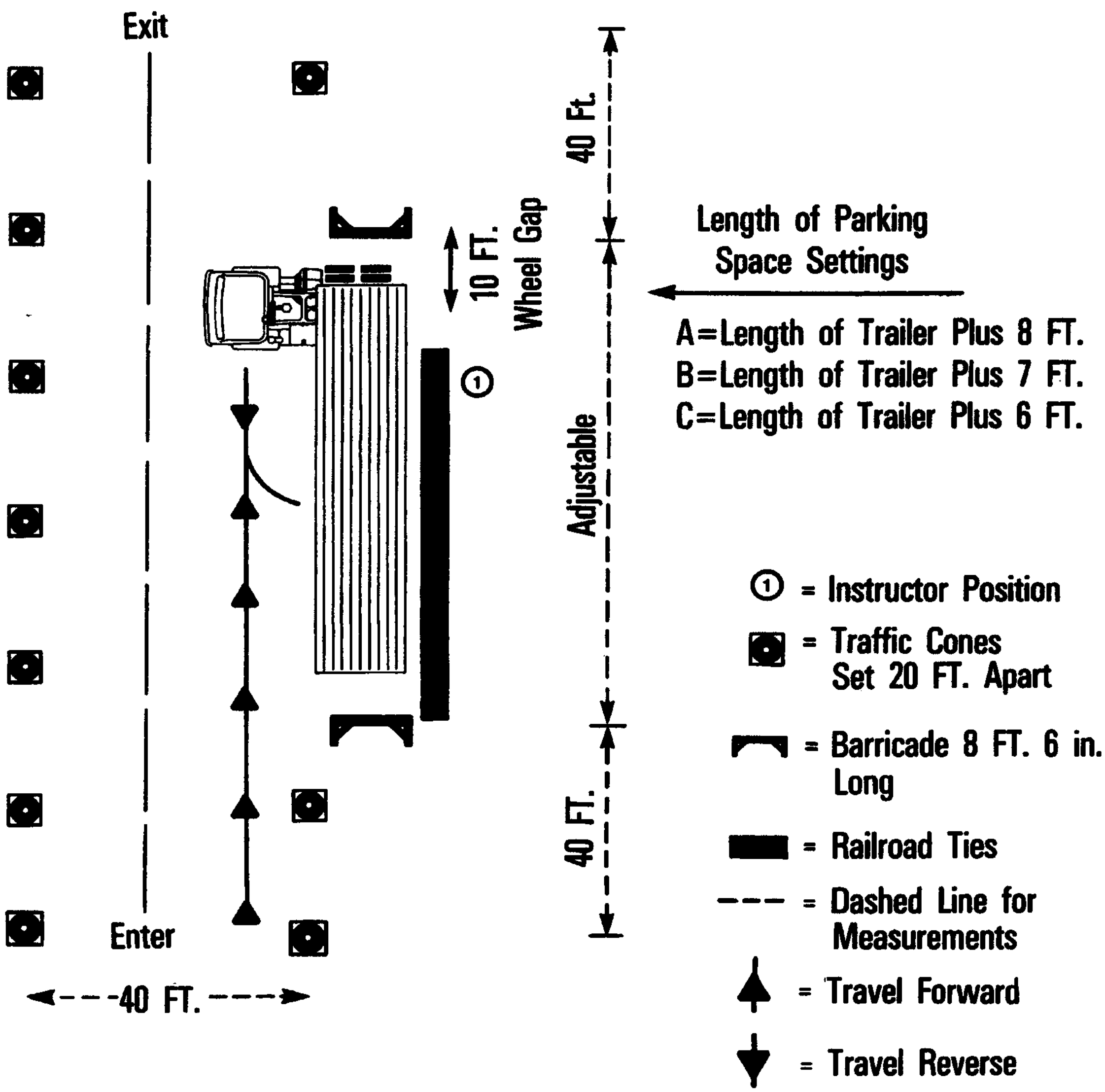
Dock Widths
A=12 FT., 10 IN.
B=12 FT., 3 IN.
C=11 FT., 8 IN.

= Barricades
= Traffic Cones Set 20 FT. Apart
= Instructor Position
= Instructor Movement
= Travel Forward
= Travel Reverse
= Dashed Line for Measurements

Range Diagram Exercise 5– Serpentine Forward and Reverse

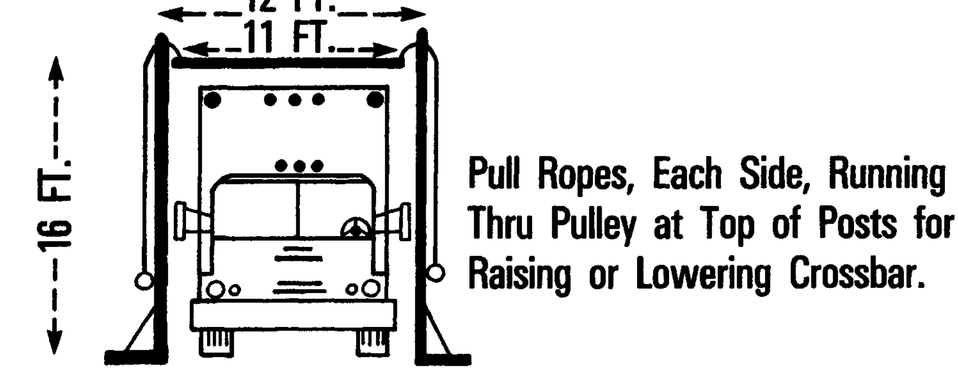


Range Diagram
Exercise 6–Parallel Parking–Jackknifed

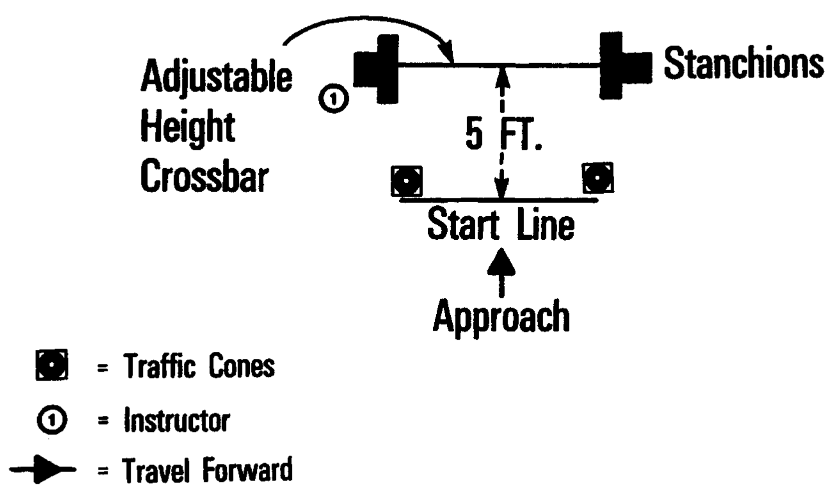


Range Diagram
Exercise 8–Overhead Clearance

Frontal View



Overhead View



Unit 2.1 VISUAL SEARCH

Purpose
The purpose of this unit is to give the student driver practice in searching the road for hazards and in monitoring critical objects such as crosswalks.

Task Objectives
1. Maintain a minimum 12-second (one city block). eye lead time.
2. Scan both sides of the road to observe roadside activity and adjacent vehicles.
3. Frequently check all mirrors for hazards.
4. Frequently check instruments.
5. Look ahead as far as possible during turns.
6. Monitor overtaking traffic and monitor incursions into blind spots.
7. Avoid diverting forward view attention for longer than 1 second.

Instruction
The student will practice adjusting the mirrors in a truck cab and understanding the different views from plane and convex mirrors. Note that this exercise may be done in simulators that are fitted with driver-adjustable mirrors (displays). The student will drive urban and highway routes and practice scanning the forward field of view and will timeshare with mirror usage and instrument scanning. The route will require that right and left turns be made at various intersections, some of which will require complete stops, while others will permit traffic to flow through. The instructor will give route-following instructions to the driver as he or she proceeds along the route.

Sufficient time is allocated for four simulator runs and four street runs. The less stressful simulator runs, coupled with the replay capability of the simulator, should aid the student's development of proper search strategies. The simulator and street sessions will involve low-traffic and moderate-traffic conditions. The street runs will be about half the duration of the simulator runs and will be alternated with the simulator runs.

PTDI Hours of Instruction

Student hours of instruction are based on the PTDI curriculum. The following table reflects the requirements for the unit.

Student Hours: Required Instruction Only

Unit	Safe Operating	Classroom	Lab	Range	Street
2.1	Visual Search	1.25	0.75	0.00	2.50

The BTW time in the following table reflects the hours of instruction for Street requirements from the PTDI curriculum. The time is distributed between the respective simulation-based training and truck-based groups.

***Simulator & Truck Time BTW Allocations* - Street**

	Conventional		Experimental	
Activity	Sim	Truck	Sim	Truck
	Hr min	Hr min	Hr min	Hr min
Low Density	0:00	1:15	0:50	0:25
High Density	0:00	1:15	0:50	0:25
Total Hours	*0:00*	*2:30*	*1:40*	*0:50*

NOTE: The preceding table addresses BTW training hours. Drivers and students need to reference Model/PTDI curriculum for additional lab and classroom requirements for this unit.

Scenario Description

The scenario route will comprise urban and highway sections. The highway route distance will be approximately 20 miles or 20 to 40 minutes duration. Instructor/driver selectable loops will be provided within the route. The mirrors will provide plane or convex views or both views, (if available in the simulator), as determined by the instructor. The scenario will include intersections, blind intersections, tight alleyway turns, multilane streets with lane drops, and freeway interchanges. Special zones, including school zones and fire stations will be provided. Traffic control devices and roadwork hazards will be included. Autonomous vehicles will provide a low level of traffic and will be used to create merge/squeeze situations and then disappear into the truck's blind spot. The autonomous vehicles will be used to pass the truck, turn in front of the truck, slow the truck down in its lane, be overtaken by the truck, confront the student driver with other traffic turning at intersections, get into the trailer's blind spot, and block the driver's view of critical information. Pedestrians will be present at crosswalks and intersections. The scenario will permit turn options at intersections to allow the instructor to drill students with as many repetitions as required to develop necessary skill levels. Failures indicated by the instrument panel, such as loss of oil pressure, will be injected to reinforce for the student the necessity of scanning instruments, as well as the mirrors and the road ahead.

Parameters

Time of day	Daylight
Weather	Clear
Traction	Dry
Terrain	Flat, hills and curves
Distances	25 miles point to point.
Road type	Various: two to four-lane urban and highway
Traffic control devices & signs	Signage and traffic lights
Other traffic	Light
ITS aids	No
Hazards	Roadwork barriers

Unit 2.2 COMMUNICATION

Purpose
The purpose of this unit is to make the student aware of the importance of communication among road users and to provide practice on how to signal other users and recognize their signals.

Task Objectives
1. Signal intention to change position on the road before doing so.
2. Cancel turn signals after turn is complete.
3. Time signals so they are not confusing to other drivers.
4. Flash brake lights to warn following traffic of slowing or stopping.
5. Use four-way flashers in accordance with state law and company policy.
6. Use headlights in daytime under conditions of low visibility.
7. Position vehicle where it can be seen by other drivers.
8. Make selective use of horn and lights to prevent collisions.
9. Limit use of CB radio to communications that will enhance safety and traffic flow.
10. Establish eye contact with drivers or pedestrians who may enter your path.
11. Avoid entering the path of other vehicles solely on the basis of a signal.

Instruction
Not all aspects of communicating intent can be practiced in a single vehicle simulator; for example, establishing eye contact with another driver or pedestrian requires the presence of that individual. Developing eye-contact behaviors requires street practice with other traffic. However, proper positioning of the vehicle and careful intrusion into the path of another vehicle can be practiced in a simulator. In addition, each simulator segment can include the training requirements of preceding segments so that overall driver workload and situation awareness requirements build throughout the segment sequence.

Intersections, lane drops, and autonomous vehicles are required to elicit signaling behaviors. Traffic control devices, slow traffic, parked vehicles, bicyclists, pedestrians and own vehicle system failures are required to elicit use of brake lights, flashers, and so on. All of these situations can be demonstrated in the simulator and in the street. On the other hand, situations requiring the use of four-way flashers (i.e., hazards) cannot be safely contrived on public roads, nor can situations requiring the use of the horn be called up on demand.

PTDI Hours of Instruction

Student hours of instruction are based on the PTDI curriculum. The following table reflects the requirements for the unit.

Student Hours: Required Instruction Only

Unit	Safe Operating	Classroom	Lab	Range	Street
1.7	Communication	1.25	0	0.00	1.00

The BTW time in the following table reflects the hours of instruction for Street requirements from the PTDI curriculum. The time is distributed between the respective simulation-based training and truck-based groups.

***Simulator & Truck Time BTW Allocations* - Street**

	Conventional		Experimental	
Activity	Sim	Truck	Sim	Truck
	Hr min	Hr min	Hr min	Hr min
Communication	0:00	1:00	0:40	0:20
Total Hours	*0:00*	*1:00*	*0:40*	*0:20*

NOTE: The preceding table addresses BTW training only. Drivers and students need to reference Model/PTDI curriculum for classroom requirements for this unit.

Scenario Description

This scenario can be split into a number of short segments: (1) Communicating intent by signal use when changing lanes; brake light, flashing before stopping. This segment requires a multilane street with a controlled intersection. (2) Communicating presence by headlight and horn use. This segment requires a crosswalk and pedestrian and a car pulling out from a parallel parking position ahead of the truck. (3) Use of four-way flashers segment for slow-moving or stopped vehicle. This segment requires a stop in a traffic lane. (4) The segment on the correct use of the CB will require that an instructor in the control room seek information from the driver regarding weather information or roadway conditions. The CB use segment will require some type of detour situation that will enable the driver to warn other truckers of the problem. (5) The last and most complex segment discussed will require hills, curves, blind intersections or entrances, and changing visibility. Changing visibility caused by fog or smog is required to demonstrate the use of headlights. Diagrams provided on the following pages offer further guidance on setting up scenarios for segments 1 through 5.

Parameters

Time of day	Daylight and twilight
Weather	Changeable clear to poor visibility
Traction	Dry
Terrain	Flat, hilly, and curves
Distances	N/A
Road type	City and highway; two-lane and four-lane
Traffic control devices & signs	Signals and signage
Other traffic	Yes
ITS aids	CB falls into this category
Hazards	Yes

Unit 2.4 SPACE MANAGEMENT

Purpose

The purpose of this unit is to give the student practice in determining the required safe distances and clearances required for safe passing, stopping, and turning. The instructor will use the simulator to demonstrate proper space management. The demonstration will include managing headway; monitoring tailgaters; managing overhead clearances, side clearances, and gaps required in traffic; and giving space to other road users. Driver attitude will be assessed for proper driving response.

Task Objectives

1. Select a lane with best mobility and least traffic interruption or interference to other vehicles.
2. Assure a safe gap before changing lanes, passing other vehicles, merging, and crossing or entering traffic.
3. Position vehicle correctly within lane and relative to crosswalks so as to minimize hazards to other road users.
4. Position the tractor and trailer appropriately in initiating and completing a turn so as to prevent other vehicles from passing on the wrong side and to minimize encroachment in other lanes.
5. Maintain a following distance appropriate to traffic, road surface, visibility, and vehicle weight.
6. Maximize separation from traffic when vehicle is disabled.
7. Avoid structures having inadequate overhead clearance.

Instruction

The student will drive a combined urban-rural route involving two-lane and four-lane roads. The practice will focus on three key skills required for space management. First, the student will learn to time acceleration in specific exercises. He or she will cross traffic from side streets, turn into traffic from side streets, and pass traffic on a four-lane highway. Second, the student will learn to estimate gaps by using a timing method. And third, he or she will learn to maintain proper following distances, lateral separations, and overhead clearances. Left and right turns and merging will be required.

PTDI Hours of Instruction

Student hours of instruction are based on the PTDI curriculum. The following table reflects the requirements for the unit.

Student Hours: Required Instruction Only

Unit	Safe Operating	Classroom	Lab	Range	Street
2.4	Space Management	1.75	0	0	1.75

The BTW time in the following table reflects the hours of instruction for Street requirements from the PTDI curriculum. The time is distributed between the respective simulation-based training and truck-based groups.

Simulator & Truck Time BTW Allocations **- Street**

	Conventional		Experimental	
Activity	Sim	Truck	Sim	Truck
	Hr min	Hr min	Hr min	Hr min
Space Management	0:00	1:45	1:10	0:35
Total Hours	*0:00*	*1:45*	*1:10*	*0:35*

NOTE: The preceding table addresses BTW training only. Drivers and students need to reference Model/PTDI curriculum for classroom requirements for this unit

Scenario Description

The scenario has three distinct segments: (1) The timing acceleration segment requires a pair of two-lane entry streets crossing a four-lane highway. The highway speed limit at the first entry street should be 30 mph and at the other, it should be 55 mph. Traffic density on the highway should be low: approximately one vehicle every halfmile on average and alternating in the curb and center lane. The intersection of the entry streets and the highway will not have traffic control devices. The simulator forward display will indicate to the driver the elapsed time as he or she makes his or her crossing or turns into the traffic flow. The highway section will be 10 miles long, with some gentle curves and mostly flat. (2) The timing gaps segment uses the same scenario elements described in the first segment, with the addition of a rural two-lane road with a lead vehicle. (3) The managing space segment requires urban, suburban, and rural streets as well as expressways. A variety of controlled and uncontrolled intersections are required including four-lanes crossing four-lanes. Some freeway sections will be hilly and include slow traffic lanes. Some blind intersections will be included with cross traffic. Traffic density should start with low density and graduate to high density. Parts of the route will have low overhanging tree limbs and low underpasses. Parked cars will be present.

Parameters

Time of day	Daylight
Weather	Clear
Traction	Dry
Terrain	Flat and rolling hills
Distances	varies
Road type	Two-lane and four-lane city streets and highways
Traffic control devices & signs	Signals and signage
Other traffic	Yes
ITS aids	No
Hazards	Yes

Unit 2.5 NIGHT OPERATION

Purpose
The purpose of this simulator exercise is to provide the student with practice in the proper use of vehicle lighting and to expose him or her to speed and space management under nighttime, reduced illumination and reduced visibility conditions.

Task Objectives
1. Adjust speed, following distance, and gap selection to nighttime conditions.
2. Use high beams wherever legally permitted.
3. Dim headlights in accordance with state laws and to minimize interference with visibility of other drivers.

Instruction
The simulator time will be used to demonstrate to the student the reduced visibility and legibility (of signs) that is associated with reduced illumination. The range and street exercises include coupling and uncoupling at night.

PTDI Hours of Instruction
Student hours of instruction are based on the PTDI curriculum. The following table reflects the requirements for the unit.

Student Hours: Required Instruction Only

Unit	Safe Operating	Classroom	Lab	Range	Street
2.5	Night Operation	0.75	0	0.75	1.50

The BTW time in the following table reflects the hours of instruction for Range & Street requirements from the PTDI curriculum. The time is distributed between the respective simulation-based training and truck-based groups.

***Simulator & Truck Time BTW Allocations* - Range & Street**

	Conventional		Experimental	
Activity	Sim	Truck	Sim	Truck
	Hr min	Hr min	Hr min	Hr min
Coupling, Pretrip, Uncoup.	0:00	0:15	0:10	0:05
Maneuvering	0:00	0:15	0:10	0:05
Backing	0:00	0:15	0:10	0:05
Highway Driving	0:00	0:30	0:20	0:10
Rural Diving	0:00	0:30	0:20	0:10
City Driving	0:00	0:30	0:20	0:10
Total Hours	*0:00*	*2:15*	*1:30*	*0:45*

NOTE: The preceding table addresses BTW training only. Drivers and Students need to reference Model/PTDI curriculum for classroom requirements for this unit.

Scenario Description

This scenario is intended to provide students with an appreciation for effects of reduced lighting and glare. Therefore, urban and rural roads with different roadway lighting are required. These roads will vary from well-lit city streets to unlit rural roads, with an ambient illumination range of 0.4 to 2.0 foot-candles (4-22 lux). Light standards will be placed according to AASHTO standards with some worse case situations having trees obscuring the luminaries. A low-contrast, high-illuminance effect will be provided for twilight when driving into the sun. The truck will have high- and low-beam lighting plus auxiliary lights. The scene luminance will change as truck headlights are switched from high to low beam. Autonomous vehicles will have high- and low-beam capability, and high beam will cause a washout of the scene contrast.

Parameters

Time of day	Twilight and nighttime
Weather	Clear
Traction	Dry
Terrain	Various flat and hilly
Distances	N/A
Road type	Various urban and rural two-lane
Traffic control devices & signs	Yes
Other traffic	Yes
ITS aids	No
Hazards	Pedestrians; vehicles coming out of side streets

Unit 2.7 PROFICIENCY DEVELOPMENT

Purpose
The purpose of this unit is to enable to the student to improve his or her skills through safe operating practices so that he or she can pass the FERT.

Task Objectives
This unit introduces no new objectives, but instead emphasizes increasing proficiency through practice.

Instruction
The simulator will be used by the instructor for review demonstration of the proper procedures in lane changing, passing, merging, exiting, turning, and parking. The students will then begin their street practice. Students experiencing specific difficulties on the street will receive additional practice developing skills in the simulator.

PTDI Hours of Instruction
Student hours of instruction are based on the PTDI curriculum. The following table reflects the requirements for the unit.

Student Hours: Required Instruction Only

Unit	Safe Operating	Classroom	Lab	Range	Street
2.7	Proficiency Development	1.00	0.00	0.00	10.5

The BTW time in the following table reflects the hours of instruction for Street requirements from the PTDI curriculum. The time is distributed between the respective simulation-based training and truck-based groups.

***Simulator & Truck Time BTW Allocations* - Street**

	Conventional		Experimental		Activity
	Sim	Truck	Sim	Truck	
	Hr min	Hr min	Hr min	Hr min	
Safe Operating	0:00	10:30	7:00	3:30	
Total Hours	*0:00*	*10:30*	*7:00*	*3:30*	

NOTE: The preceding table addresses BTW training only. Drivers and students need to reference Model/PTDI curriculum for classroom requirements for this unit.

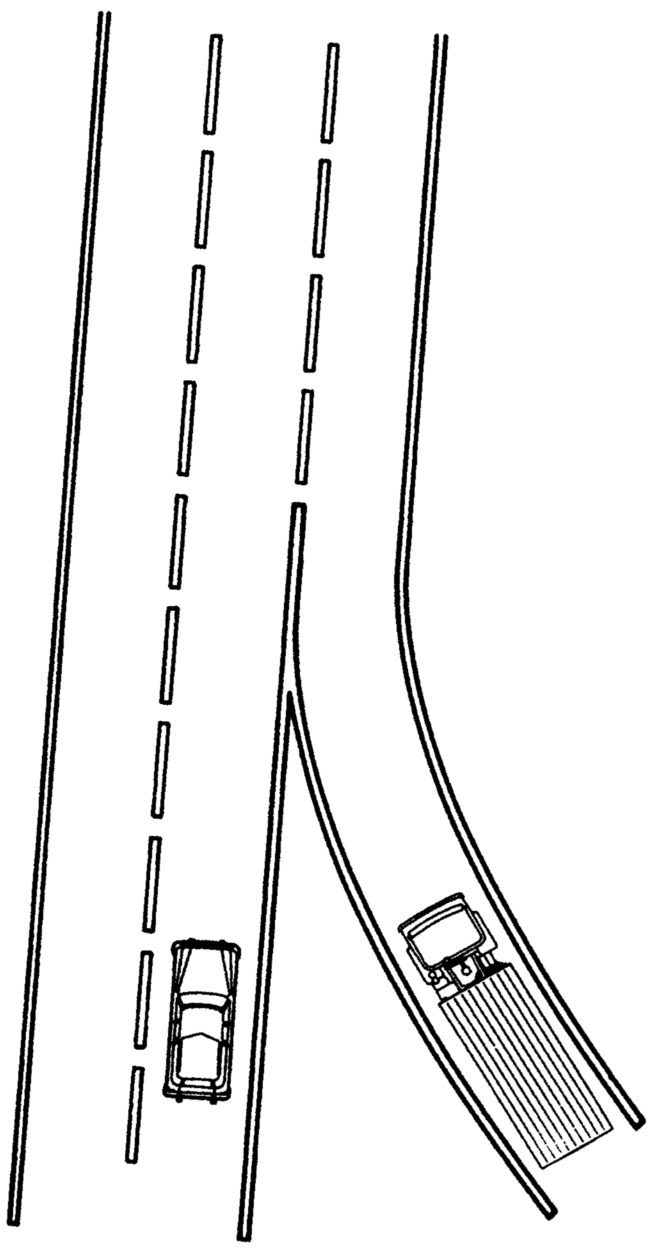
Scenario Description
The instructor demonstration scenario will provide a multilane highway environment with realistic traffic levels. The scenario will include on/off ramps to allow loops for quick repeat demonstrations of the specific procedures outlined in the introduction. The highway section should be about 5 miles, with the ramp geometry as shown in the following pages (Visuals 3 and

4). Autonomous vehicles will be provided for the passing demonstrations. An intersection (Visual 5) and an alleyway loading section (Visual 7) will be provided. This scenario be provided with changeable weather conditions. If required, student practice will take place on the same scenario, but be limited to the sections in which skill building and remedial instruction is required.

Parameters

Time of day	Daylight
Weather	Various
Traction	Wet and dry
Terrain	Various
Distances	N/A
Road type	Mainly two-lane and four-lane highway with adjacent service streets.
Traffic control devices & signs	Yes
Other traffic	Yes
ITS aids	No
Hazards	No

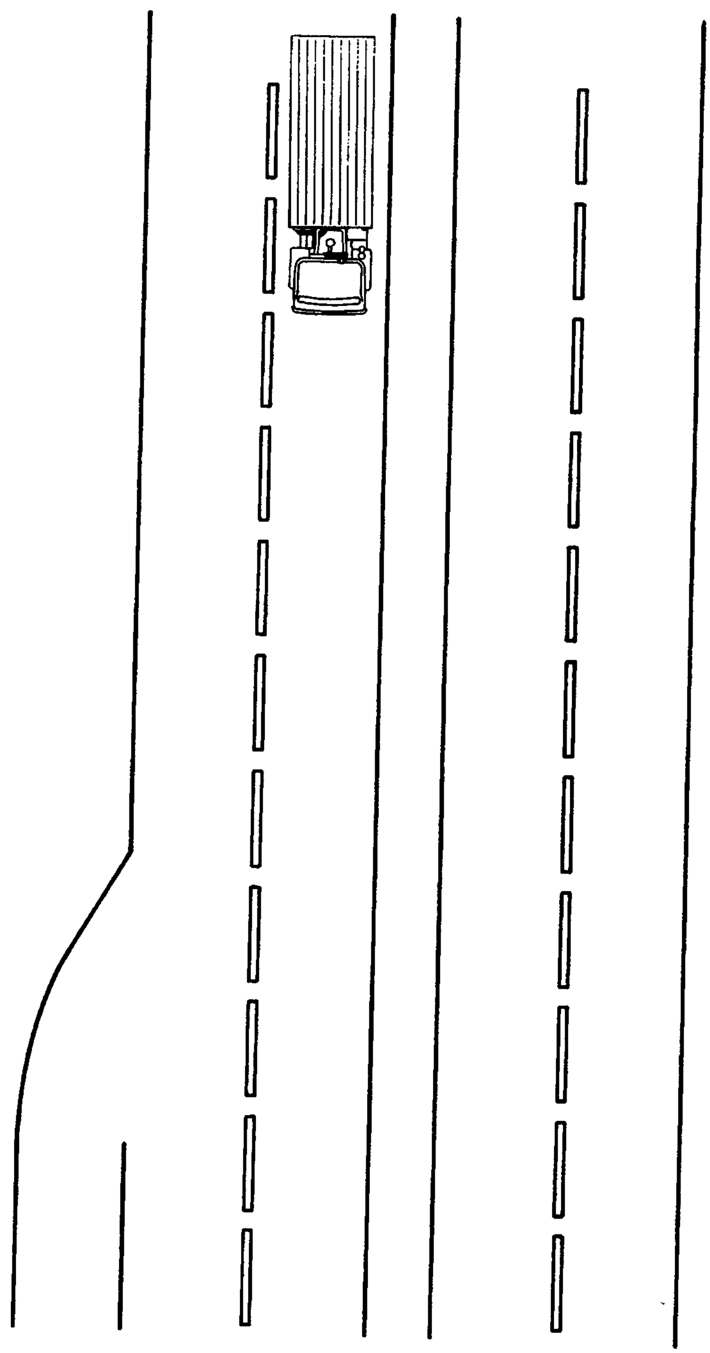
Visual 3



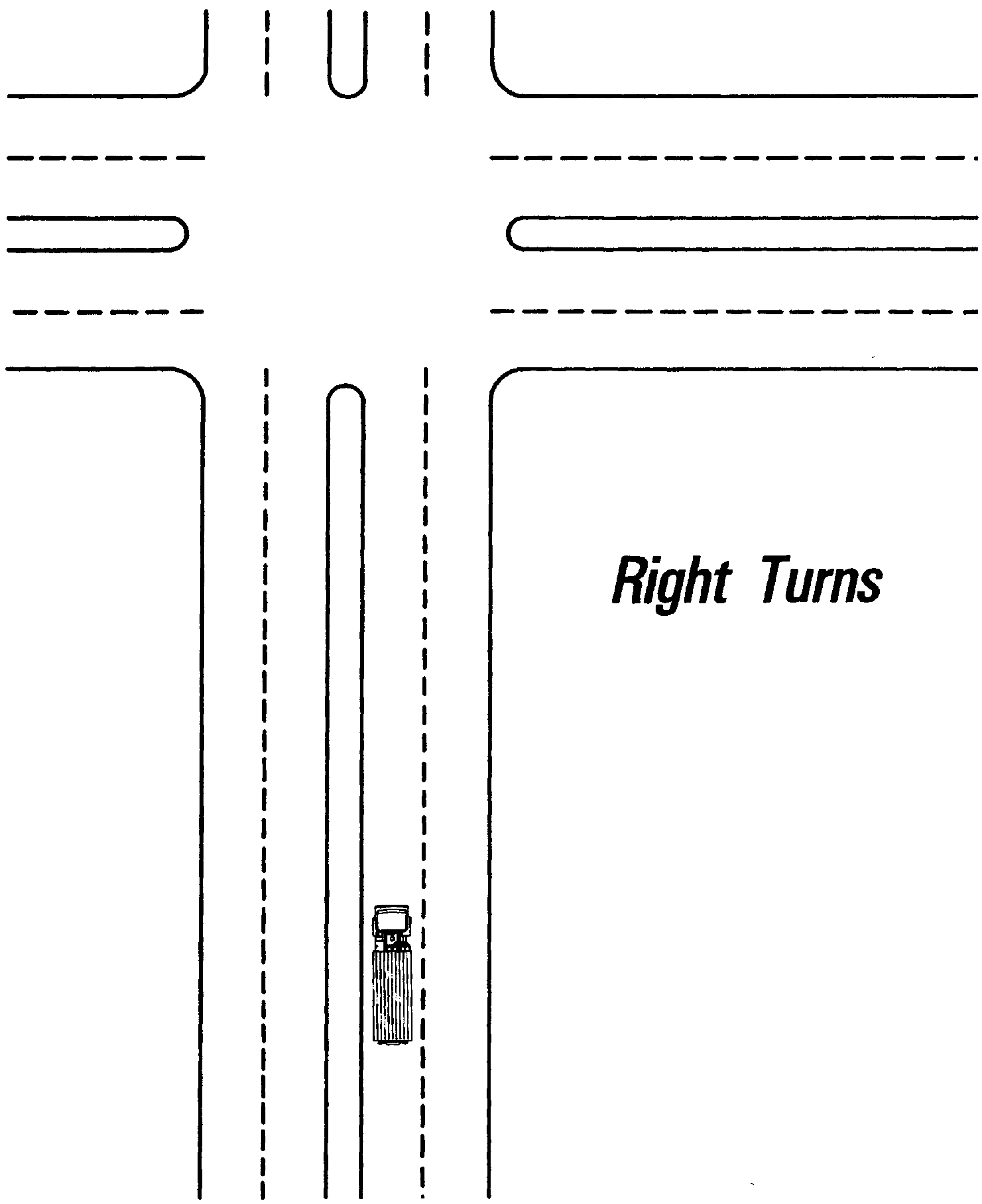
Merging

Visual 4

Exiting

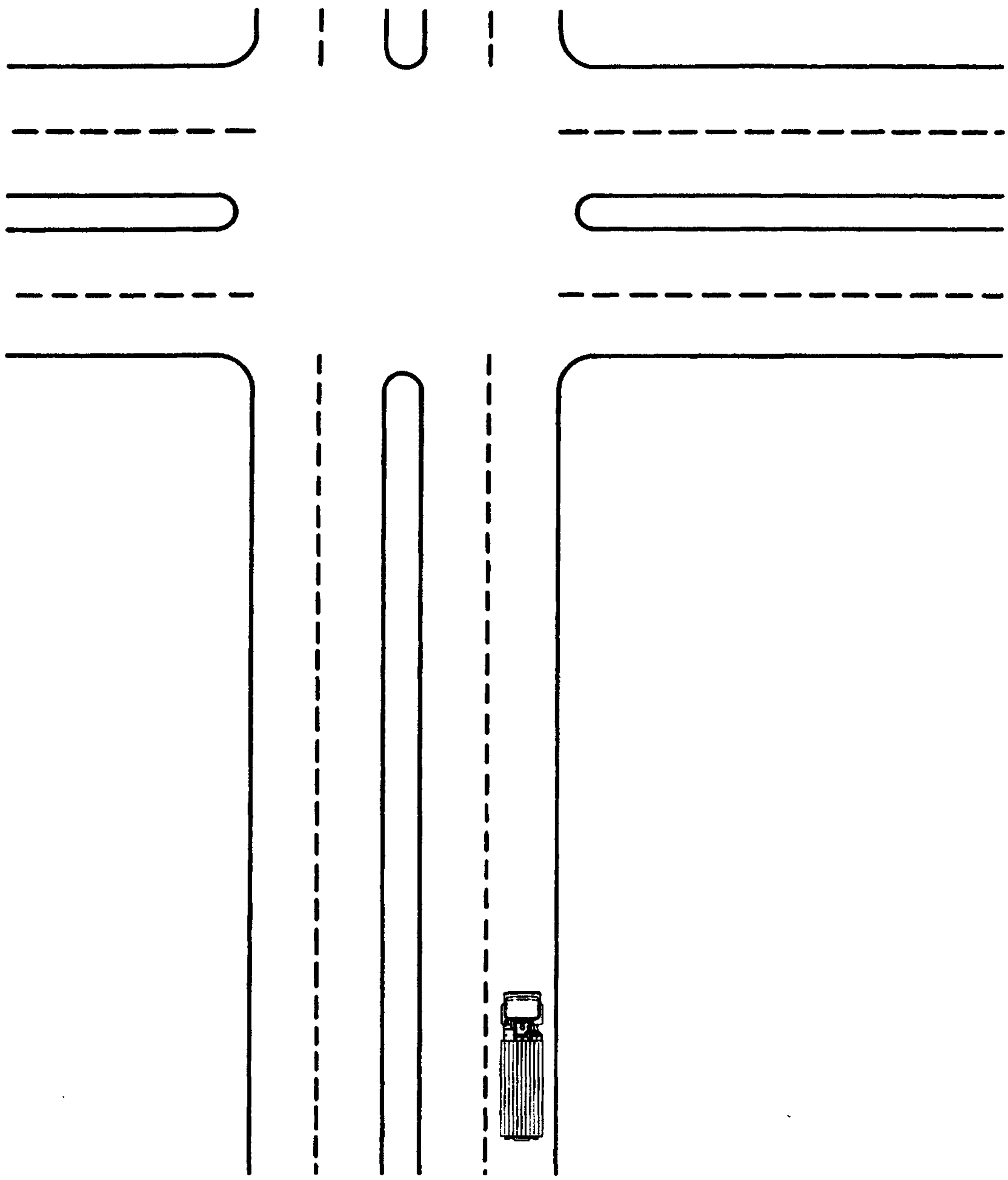


Visual 5



Visual 6

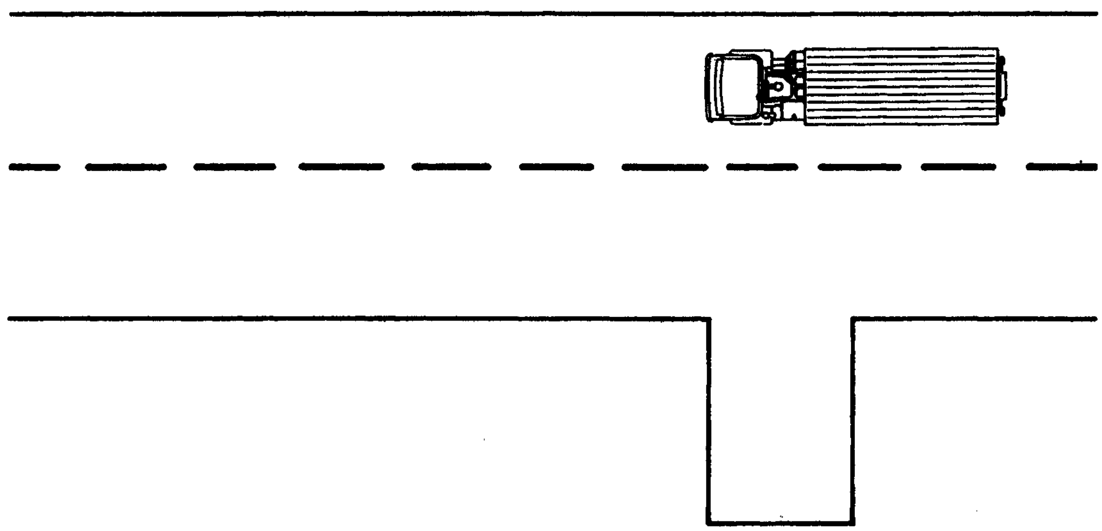
Left Turns



Visual 7

Parking Procedure

Alley Dock



A.2 ADVANCED CAPABILITIES

Notes: 1 The following advanced capabilities scenarios are for general guidance in the research design. The final determination regarding the components of each unit will be tailored to the simulator selected.

2 Amount of time for each of the advanced capabilities scenarios is dependent on the requirements of the scenario descriptions.

Unit 1.9 SPECIAL RIGS

Purpose

The purpose of this unit is to expose the student to special rigs; i.e., triples, doubles, and tankers. Because BTW is not required in the FHWA Model/PTDI Tractor-Trailer Driver Curriculum, this unit will be trained entirely in the simulator. The field observations will be replaced by individual experiences, with each student driver driving different rig configurations under the varying conditions that can be produced in the simulator. This unit is not part of the BTW driving skills portion for the CDL.

Task Objective

1. Determine whether they can safely operate any type of special rig.

Scenario Description

The standard 20-mile point to point route from Unit 1.5 can be used. As in Unit 1.8, two traffic levels can be provided to highlight the difficulty of handling long combinations in traffic. Different rig configurations, including multiple combination vehicles can be driven back and forth over the route to help students appreciate the impact of narrow city streets and mountainous terrain, slosh from tankers, and acceleration, braking, and cornering in special rigs.

Parameters

Time of day	Daylight
Weather	Clear
Traction	Varying dry and wet
Terrain	Flat
Distances	N/A
Road type	Hills and curves.
Traffic control devices & signs	Stop lights and signs
Other traffic	
ITS aids	No
Hazards	No

Unit 2.3 SPEED MANAGEMENT

Purpose

In the FHWA Model Curriculum, this unit provides only an instructor demonstration of managing speed. The purpose of this unit can be better achieved in the simulator, which can provide the students with both an instructor demonstration and the opportunity to experience the effect of traffic flow on a heavy tractor-trailer while driving it themselves.

The range demonstrations in the FHWA Model Curriculum are limited to showing the effect of vehicle speed on distance traveled while the driver reacts to a braking and while the vehicle is under braking. This demonstration can be replaced by individual experiences for each driver using the variable conditions that can be produced in the simulator. Data on speed and stopping distances are provided in the visuals of Unit 2.3 of the Model Curriculum. The student will be exposed to the interaction of speed and stopping distance, load and stopping distance, surface traction (wet and dry) and stopping distance, speed and curves, speed and grades, speed and traffic flow, and speed and visibility. The need to carefully assess road conditions when determining speed management will be emphasized. Finally, costs associated with exceeding the speed limits in terms of fuel consumption will be demonstrated in the simulator.

Task Objectives

1. Adjust speed to prevailing conditions: road condition, weather, visibility, traffic, load, vehicle, and driver.
2. Obey the legal speed limit.

Scenario Description

Two segments are required: (1) a stopping distance segment and 2) a street demonstration segment. The stopping segment will be a special 2-mile, straight road, braking section with a moderate serpentine curve at the end. A "brake now" red signal light will be installed at the side of the roadway and will be triggered as the truck reaches the zero distance of the braking run. From the zero distance, distance hash marks will be painted on the roadway every 20 feet and continue around the serpentine curve. A second zero point will be used for curve braking These markings should include the distance (in large characters on the road) from the braking zero point so that student observers monitoring via the birds-eye-view can see the stopping distances immediately. A street segment will use an urban route and a highway route based on the scenario from Unit 1.5. The essential difference in this case is the addition of different vehicles and different weather, visibility, and roadway traction characteristics required to demonstrate dry, wet, hydroplaning, visibility limitations, and traffic flow limitations. A red light, a vehicle pullout, and an incursion by an obscured pedestrian into the driver's path are suggested for the street demonstration.

Parameters

Time of day	Day, twilight, night
Weather	Varies
Traction	Varies; dry and wet
Terrain	Varies; hills and curves
Distances	20 miles, street segment
Road Type	
Traffic control	No
Devices & Signs	No
Other traffic	No
ITS Aids	No
Hazards	No

Unit 2.6 EXTREME DRIVING CONDITIONS

Purpose

The purpose of this unit is to give the student experience in preparing his or her vehicle and operating it in (1) adverse weather, (2) desert, and (3) mountainous routes. The simulator will be used to give the student a better appreciation of reduced visibility in rain and fog and the opportunity to practice driving on slippery surfaces (e.g., black ice, sun and shade, skid recovery), and in driving up and down steep grades.

Task Objectives

1. Prepare for operation in cold weather; remove snow and ice from windows, mirrors, brakes, lights, hand and toe holds etc.; and install tire chains when necessary.
2. Inspect for cold weather operation.
3. Make sure that moisture is expelled from the airbrake after each trip.
4. Obtain weather information before and during trips.
5. Adjust vehicle operation to weather conditions including, speed selection, braking, direction changes, and following distances.
6. Observe road surface for changes in conditions.
7. Use right lane or special truck lane going up grades.
8. Select proper gear for engine braking before starting down grade.
9. Use proper braking techniques and maintain proper engine speed on long down grades.
10. Properly use special speed reduction devices (e.g., engine exhaust brakes).
11. Monitor engine temperature gauge when pulling heavy loads up long mountain grades.

Scenario Description

The scenario will consist of two segments, both based on the scenario used for unit 1.5: a desert and mountain segment and a winter driving segment. The mountain segment will be based on Unit 1.5 with the addition of some steeper grades in the mountain sections (8 percent), with maximum grade lengths of 5,000 feet or more for the steepest sections. This segment will also have a mountain escape ramp filled with sand or gravel. The ramp will have a 43 percent grade and a length of 1,500 feet. Down grade to ramp will be 7 percent for 1 mile. The winter segment will be on the same rural, winding and hilly road used for the desert and mountain segment, but with the steepest grades missing, and with the surface varying from dry to wet, including patches of black ice. This segment will also vary the visibility level suddenly to simulate the effects of rain squalls or blowing snow.

Parameters

Time of day	Daylight
Weather	Various
Traction	Dry, slippery, wet
Terrain	Flat and mountainous
Distances	N/A
Road type	Rural two-lane and four-lane
Traffic Control Devices & Signs	N/A
Other Traffic	No
ITS Aids	No
Hazards	No

Unit 3.2 EMERGENCY MANEUVERS

Purpose

The purpose of this Unit is to develop the student's proficiency in handling emergency stops, evasive steering, off-road recoveries, brake failures, and blowouts. All of these situations can be practiced in the simulator. Brake failures and blowouts are not practiced on the range. The student will practice the range-type exercises in the simulator before going on the range and later will practice the adaptation of these exercises to a street environment in the simulator.

Task Objectives

1. Stop the truck in the shortest possible distance on a dry surface.
2. Perform a quick evasive turn on a dry surface.
3. Make an evasive turn off the roadway and back onto it while maintaining directional control.
4. Maintain control of the vehicle in the event of a blowout.
5. Assessment of other emergency maneuvers as appropriate, such as, jackknife.

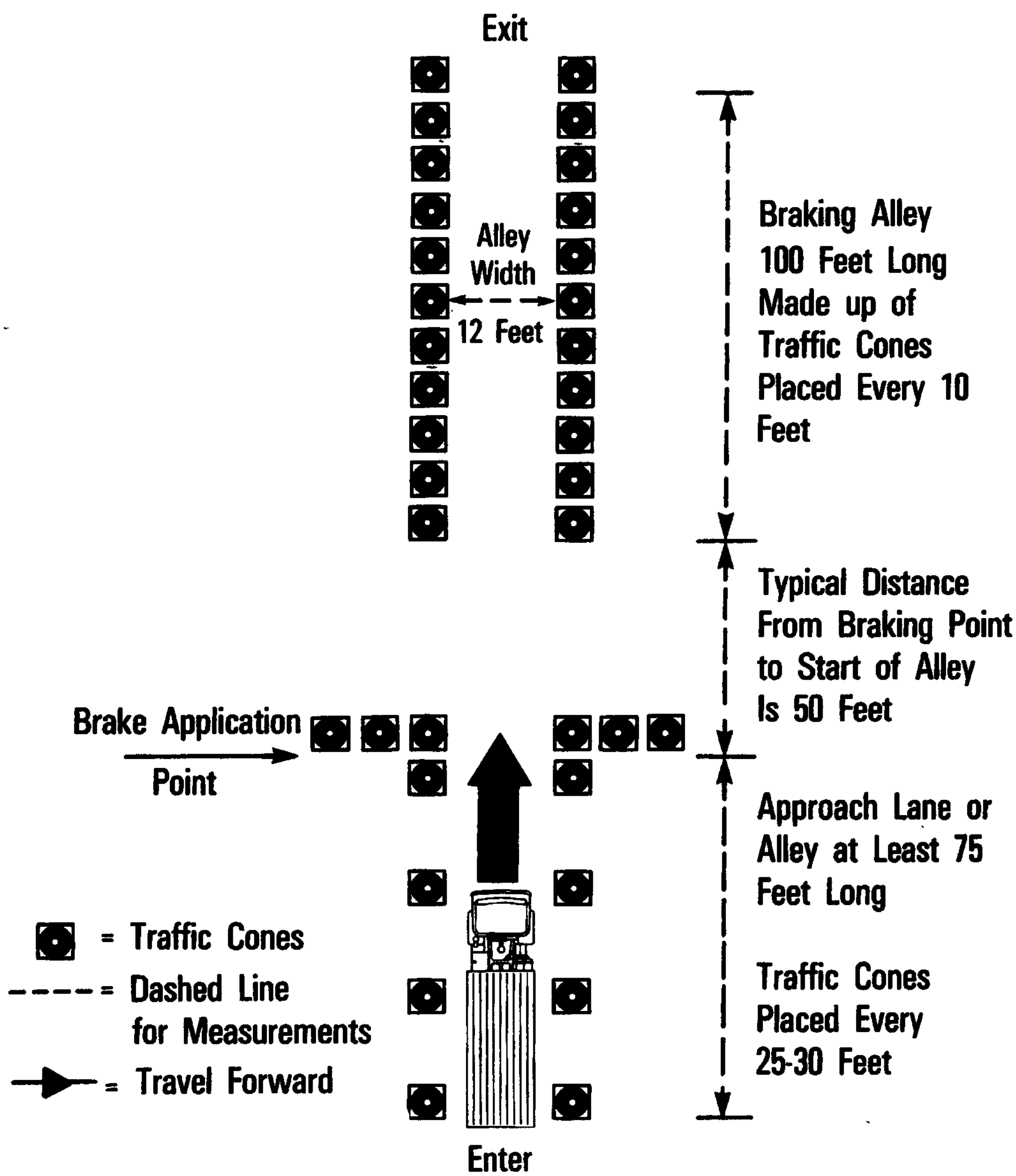
Scenario Description

The simulator must have an adequate vibration or motion base for the off-road recovery and blowout recovery exercises. This scenario will have two segments. The first will replicate the situations in the following pages, Emergency Stop, Evasive Steering, and Off-road Recovery. The second will be based on Unit 1.5, Shifting. In addition, it will have autonomous vehicles, bicyclists, and pedestrians that can function as hazards, causing the student to perform an emergency straight line stop, an evasive maneuver around the vehicle, and an evasive maneuver with an off- road recovery. In the latter case, the roadway will have a soft shoulder lower than the road surface. The scenario will also have roadway debris, such as a lost wheel, which can be used as a hazard to initiate emergency maneuvers.

Parameters

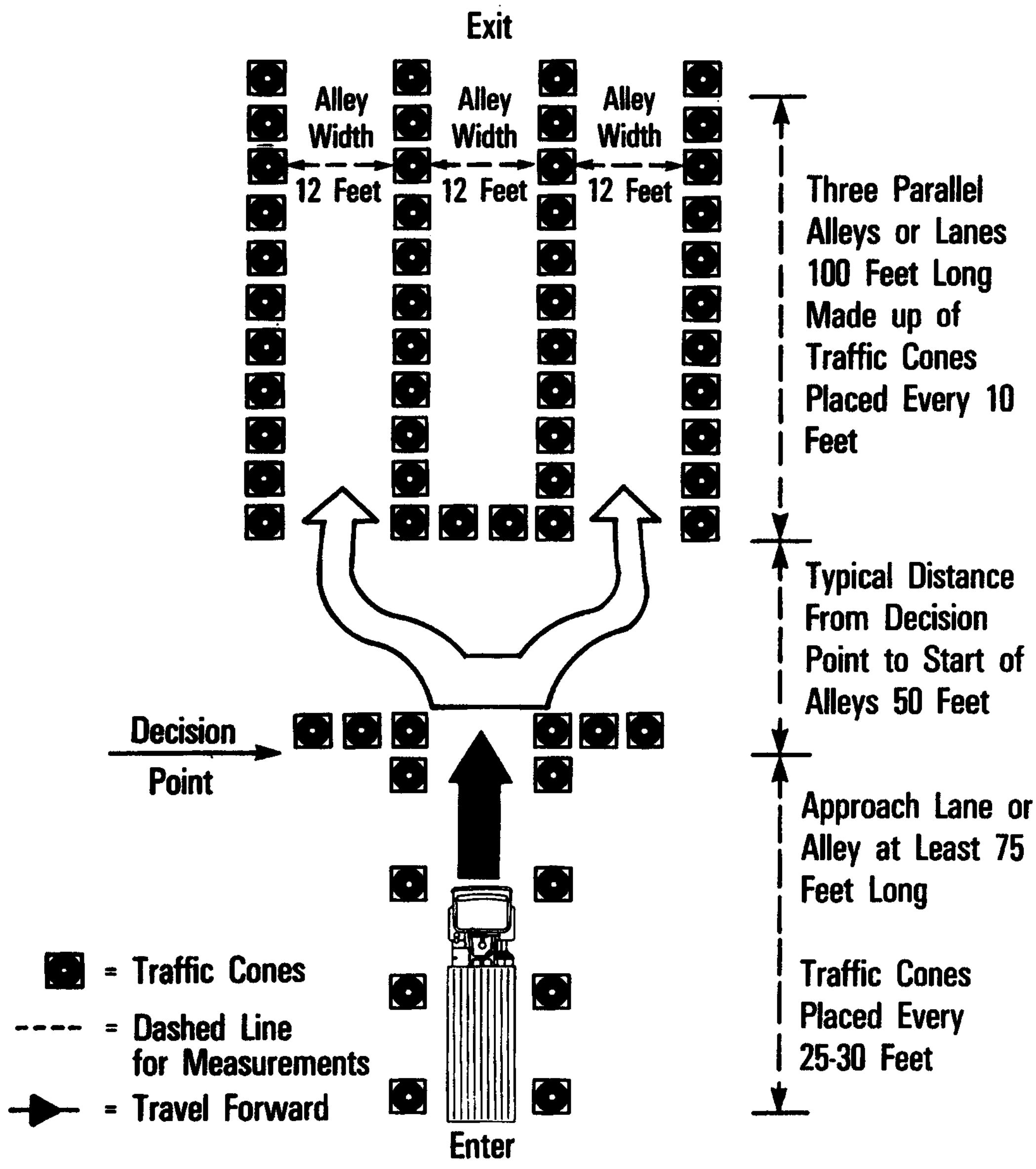
Time of day	Daylight
Weather	Clear
Traction	Dry
Terrain	Flat
Distances	N/A
Road type	Driving range and street
Traffic control devices & signs	N/A
Other traffic	Yes
ITS aids	No
Hazards	Stopped vehicles, debris

Range Diagram–Exercise 1



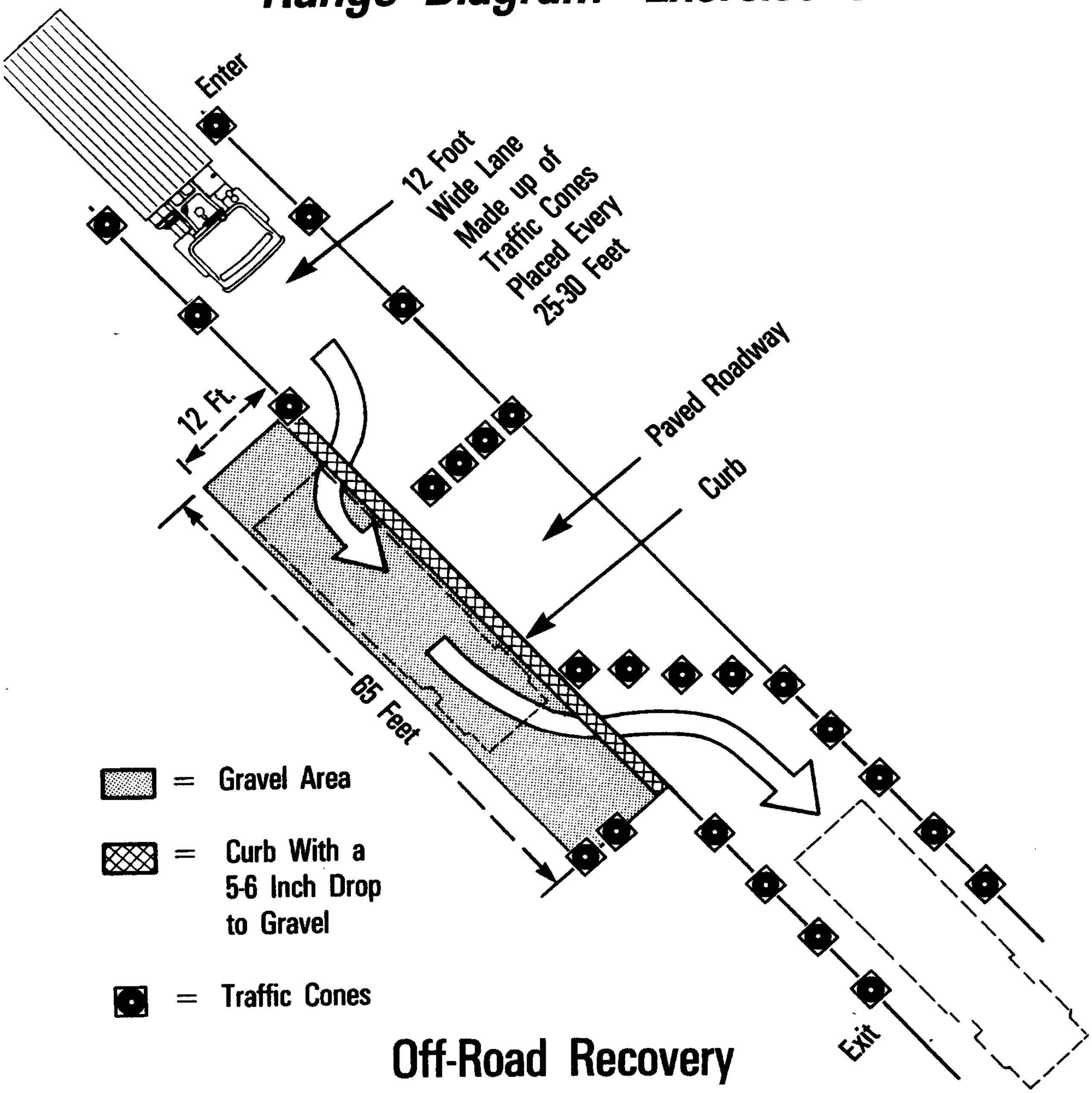
Emergency Stop

Range Diagram–Exercise 2



Evasive Steering

Range Diagram—Exercise 3



Off-Road Recovery

APPENDIX B
ADVANCED CAPABILITIES

B.1. SAMPLE ADVANCED CAPABILITIES QUESTIONNAIRE

B.2. SAMPLE INSTRUCTOR'S RATING SCALE

Instructor Identification Number: _____

Sample Advanced Capabilities Questionnaire
(To be completed by experienced drivers)

Directions: Please answer the following questions to the best of your knowledge.

1. Have you experienced any of the following hazardous, dangerous situations during actual driving. If "yes", mark which ones?

____
(Yes or No)

__jackknife
__tire blowout
__black ice
__blowing snow
__tire fire
__cab fire
__gusting wind
__air brake failure
__high-speed evasive maneuver
__other (please specify)

____

2. How many years of professional tractor-trailer driving experience do you have? _____

3. How many endorsements do you currently carry? _____

Please mark each endorsement that applies and indicate how many years you have had the endorsement,

__school bus	__years
__tank cargo	__years
__doubles	__years
__triples	__years
__hazardous materials	__years
__other (please specify)	
______________________	__years
______________________	__years

4. Have you participated in any remedial training within the last year? _____

(Yes or No)

Directions: Rate each of the following questions on a scale of 1 to 5 according to your perception of simulator effectiveness for each of the scenarios.

1 --------------2---------------3-------------4------------------5

1	3	5
Not At All Effective	Somewhat Effective	Very Effective

5. How similar in *shifting* to a tractor-trailer was the simulator for the vehicle configuration of *doubles*? _____

6. How similar in *braking* to a tractor-trailer was the simulator for the vehicle configuration of *doubles*? _____

7. How similar in *steering* to a tractor-trailer was the simulator for the vehicle configuration of *doubles*? _____

8. How similar in *acceleration* to a tractor-trailer was the simulator for the vehicle configuration of *doubles*? _____

9. How similar in *shifting* to a tractor-trailer was the simulator for the vehicle configuration of *triples*? _____

10. How similar in *braking* to a tractor-trailer was the simulator for the vehicle configuration of *triples*? _____

11. How similar in *steering* to a tractor-trailer was the simulator for the vehicle configuration of *triples*? _____

12. How similar in *acceleration* to a tractor-trailer was the simulator for the vehicle configuration of *triples*? _____

13. How similar in *shifting* to a tractor-trailer was the simulator for the *various loads and stopping distances*? _____

14. How similar in *braking* to a tractor-trailer was the simulator for the *various loads and stopping distances*? _____

15. How similar in *steering* to a tractor-trailer was the simulator for the *various loads and stopping distances*? _____

16. How similar in *acceleration* to a tractor-trailer was the simulator *for the various loads and stopping distances*? _____

17. How similar in *shifting* to a tractor-trailer was the simulator for the *evasive maneuver*? _____

18. How similar in *braking* to a tractor-trailer was the simulator for the *evasive maneuver*? _____

19. How similar in *steering* to a tractor-trailer was the simulator for the *evasive maneuver*? _____

20. How similar in *acceleration* to a tractor-trailer was the simulator for the *evasive maneuver*? _____

21. How similar in *shifting* to a tractor-trailer was the simulator for the *tire failure*? _____

22. How similar in *braking* to a tractor-trailer was the simulator for the *tire failure*? _____

23. How similar in *steering* to a tractor-trailer was the simulator for the *tire failure*? _____

24. How similar in *acceleration* to a tractor-trailer was the simulator for the *tire failure*? _____

25. To what degree did the simulator convey a sense of realism for the visible characteristics of the road (e.g., signage, pavement type)? _____

26. How convincing was the simulator in providing the overall impression of potential threat? _____

27. To what extent do you think the simulator challenged your skills for the various scenarios? _____

28. To what extent do you think simulation may be useful for enhancing the *training* of commercial vehicle operators? _____

29. To what extent do you think simulation may be useful for enhancing the *testing* of commercial vehicle operators? _____

30. To what extent do you think simulation may be useful for enhancing the *licensing* of commercial vehicle operators? _____

31. What was your overall impression of the realism portrayed by each of the following scenarios? (Please be critical.)

Special rigs:

Emergency maneuvers:

Speed management:

Extreme driving conditions:

32. What would you change about the scenarios to provide a more appropriate tool for assessing the advanced driving capabilities?

33. If you had to identify three points you like least about the simulator and three points you like most about the simulator, what would they be?

(Least)	(Most)
1.	1.
2.	2.
3.	3.

34. Do you think training in a simulator will help you in a real driving environment?

35. Please list any other comments.

Instructor Identification Number: _____

Sample Instructor's Rating Scale
(for advanced capabilities; 1 per scenario)

Directions: Using the following 5-point scale rate each driver on the following performance factors for each scenario according to the degree you think he or she exercised proper procedure for efficiency and safety.

1----------2-----------------3 --------------4--------------5

Minimum	Average	Maximum

1. Vehicle Control

Efficiency	1	2	3	4	5
Safety	1	2	3	4	5

2. Following Distance

Efficiency	1	2	3	4	5
Safety	1	2	3	4	5

3. Speed Selection

Efficiency	1	2	3	4	5
Safety	1	2	3	4	5

4. Braking

Efficiency	1	2	3	4	5
Safety	1	2	3	4	5

5. Shifting

Efficiency	1	2	3	4	5
Safety	1	2	3	4	5

APPENDIX C

PROFESSIONAL TRUCK DRIVER INSTITUTE OF AMERICA
HOURS OF INSTRUCTION
STUDENT HOURS: REQUIRED INSTRUCTION ONLY

		MINIMUM CLOCK HOURS			
Unit		CLASSROOM	LAB	RANGE	STREET
	BASIC OPERATION				
1.1	Orientation	3.25	1.00	0	0
1.2	Control Systems	1.75	0.75	0	0
1.3	Vehicle Inspection	2.00	4.00	0	0
1.4	Basic Control	0.75	0	2.25	
1.5	Shifting	1.25	0	0.75	0
1.6	Backing	0.75	0	7.00	0
1.7	Coupling and Uncoupling	0.75	0	1.00	0
1.8	Proficiency Development: Basic Ctrl.	1.50	0	7.00-10.00	6.00
1.9	Special Rigs	1.00	0	0	0
	SAFE OPERATING PRACTICES				
2.1	Visual Search	1.25	0.75	0	2.50
2.2	Communication	1.25	0	0	1.00
2.3	Speed Management	2.00	1.75	0	0
2.4	Space Management	1.75	0	0	1.75
2.5	Night Operation	0.75	0	0.75	1.50
2.6	Extreme Driving Conditions	3.25	4.00	0	0
2.7	Proficiency Development: Safe Oper.	1.00	0	0	7.50-10.50
	ADVANCED OPERATING PRACTICES				
3.1	Hazard Perception	1.50	0	0	2.00
3.2	Emergency Maneuvers	2.50	0	0	0
3.3	Skid Control and Recovery	2.50	0	0	0
	VEHICLE MAINTENANCE				
4.1	Vehicle Systems	11.25	2.00	0	0
4.2	Preventive Maintenance and Servicing	1.25	7.50	0	0
4.3	Diagnosing and Reporting Malfunctions	3.00	1.00	0	0
	NONVEHICLE ACTIVITIES				
5.1	Handling Cargo	5.00	2.00	0	0
5.2	Cargo Documentation	4.75	0	0	0
5.3	Hours of Service Requirements	5.75	0	0	0
5.4	Accident Procedures	3.00	0.75	0	0
5.5	Personal Health and Safety	5.00	0	0	0
5.6	Trip Planning	4.75	0	0	0
5.7	Public and Employer Relations	3.50*	0	0	0
		78.00	25.50	18.75 to 21.75	22.25 to 25.25
	TOTAL	78.00	25.50	44.00*	147.50

*Total of range and street must equal at least 44 clock hours.

APPENDIX D
PSRT AND FERT TEST

D.1 SCORE SHEETS—PSRT AND FERT
D.2 SUMMARY OF CRITERIA RANGE TEST IN/END COURSE

Score Sheet—PSRT AND FERT

Exercise		Score	
BACKING - STRAIGHT LINE			
1	Motion Control	YES	NO
2	Contact	YES	NO
3	Time	YES	NO
OFFSET ALLEY			
4	Motion Control	YES	NO
5	Contact	YES	NO
6	Time	YES	NO
ALLEY DOCK			
7	Motion Control	YES	NO
8	Contact	YES	NO
9	Distance	YES	NO
10	Time	YES	NO
ALLEY DOCK - JACKKNIFED			
11	Motion Control	YES	NO
12	Contact	YES	NO
13	Distance	YES	NO
14	Jackknife Position	YES	NO
15	Time	YES	NO
SERPENTINE/FORWARD			
16	Motion Control	YES	NO
17	Contact	YES	NO
18	Time	YES	NO
SERPENTINE/REVERSE			
19	Motion Control	YES	NO
20	Contact	YES	NO
21	Time	YES	NO
PARALLEL PARKING - JACKKNIFED			
22	Motion Control	YES	NO
23	Contact	YES	NO
24	Distance	YES	NO
25	Time	YES	NO
CONTROLLED STOP LINE			
26	Distance	YES	NO
27	Smoothness	YES	NO
OVERHEAD CLEARANCE			
28	Correct Decision	YES	NO
29	Time	YES	NO

Student ______________________________

(See Next Page for Definitions)

Exercise		Score	
PRETRIP INSPECTION			
30	Approaching Vehicle	YES	NO
31	Under Hood	YES	NO
32	Inside Cab	YES	NO
33	Lights	YES	NO
34	Walkaround Vehicle	YES	NO
35	Signal Lights	YES	NO
36	Air Brake System	YES	NO
37	Problems	YES	NO
38	Time	YES	NO
COUPLING			
	(Pre-Couple)		
39	Motion Control	YES	NO
40	Contact	YES	NO
41	Chocks	YES	NO
42	Air Hookup	YES	NO
43	Air Supply	YES	NO
44	Trailer Brakes	YES	NO
45	Hookup	YES	NO
46	Test Hookup	YES	NO
47	Inspects Coupling	YES	NO
	(Post Couple)		
48	Electrical Hookup	YES	NO
49	Landing Gear	YES	NO
50	Chocks	YES	NO
51	Time	YES	NO
UNCOUPLING			
	(Pre-Uncoupling)		
52	Positions Vehicle	YES	NO
53	Trailer Air Off	YES	NO
54	Secures Tractor	YES	NO
55	Lowers Landing Gear	YES	NO
56	Disconnect Lines	YES	NO
57	Stores Lines	YES	NO
58	Fifth Wheel Release	YES	NO
	(Uncouple)		
59	Pulls Tractor Forward	YES	NO
60	Secures Tractor	YES	NO
	(Post-Uncouple)		
61	Checks Landing Gear	YES	NO
62	Pulls Tractor Clear	YES	NO
63	Time	YES	NO

Total # Passed _____Total # Failed_____

Percent Correct____________________

Examiner__________________________________

Source: U.S. Department of Transportation (1985). Model Curriculum for Training Tractor-Trailer Drivers, Part One. Washington, D. C.: U. S. Printing Office.

Summary of Criteria Range Test In/EndCourse

BACKING—STRAIGHT LINE
Motion Control: No changes or stops
Contact: Does not touch lane boundaries
Time: 90 sec. in course; 60 sec. at end-of-course

OFFSET ALLEY
Motion Control: No changes or stops
Contact: 2 or less touches; 1 or no hits in course; no touches or hits at end-of-course
Time: 90 sec. In course; 45 sec. at end-of-course

ALLEY DOCK
Motion Control: 4 or less changes or stops in course; 2 or less at end-of-course
Contact: 2 or less boundary/barricade touches or hits in course; none allowed at end-of-course
Distance: Stops 24 in. Or less from back of dock; 12 in or less at end-of-course
Time: 4 min 30 sec. In corse; 2 min. 30 sec at end-of-course

ALLEY DOCK—JACKKNIFED
Motion Control: 4 or less changes or stops in course; 2 or less at end-of-course
Contact: 2 or less boundary/barricade touches in course; none allowed at end-of-course
Distance: Stops 30 in. Or less from dock (no hit) in course; 18 in. Or less (no hit) end-of-course
Jackknife Position: Leaves tractor 90 degrees to trailer
Time: 4 min 30 sec. In course; 2 min 45 sec at end-of-course

SERPENTINE—FORWARD
Motion Control: No changes or stops
Contact: No touching or hitting drums or street boundary delineators
Time 60 sec. In course; 45 sec. At end-of-course

SERPENTINE—REVERSE
Motion Control: 4 or less changes or stops in course; 2 or less at end-of-course
Contact: No touching or hitting drums or street boundary delineators
Time: 4 min. Or less in course; 2 min 30 sec. Or less at end-of-course

PARALLEL PARKING—JACKKNIFED
Motion Control: 4 or less changes or stops in course; 2 or less changes or stops at end-of-course
Contact: 2 or less curb touches, no curb crosses or barricade hits in course; none at end-of -course
Distance: Trailer 24 in. Or less from curb in course; 12 in. Or less at end-of-course.
Time: 4 min. In course, 2 min. 30 sec. At end-of-course

CONTROLLED STOP LINE
Distance: Stops 18 in. Or less from line in course; 6 in. Or less at end-of-course
Smoothness: Minor nose rebound and audible air release allowed in course; none allowed at end-of-course

PRETRIP INSPECTION
Inspects required components in Items 30 thru 36 identifies all simulated defects
Time: 30 min. In course; 15 min. At end-of-course

COUPLING
(Pre-Couple)
Motion Control: 3 or less changes or stops in course; 1 or less at end-of-course
Contact: Tractor backed slowly, 5th wheel jaws just touch (not hit) pickup apron
Chocks: Chocks front and back of left trailer wheels
Air Hookup: Lines not crossed
Air Supply: Supplies air to trailer
Trailer Brakes: Applies trailer brakes
(Couple)
Hookup: Backs slowly until 5th wheel engages kingpin
Test Hookup: Moves forward checking hookup (Twice)
Inspects Coupling: Visually checks by crawling under trailer
(Post Couple)
Electrical Hookup: Hooks up cable
Landing Gear: Raises landing gear fully, secures crank handle
Chocks: Removes trailer wheel chocks
Time: 18 min. In course; 8 min. At end-of-course

UNCOUPLING
(Pre-uncouple)
Positions vehicle
Shuts off trailer air supply
Secures tractor
Lowers landing gear proper distance
Disconnects and properly stores air and electrical lines
Releases fifth wheel latch
(Uncouple)
Pulls tractor forward only until 5th wheel is clear
Secures tractor with frame ends under trailer nose
(Post-Uncouple)
Checks trailer landing gear for stability
Pulls tractor clear from trailer
Time: 10 min. In course; 5 min. At end-of-course

APPENDIX E

SIMULATION SICKNESS QUESTIONNAIRE

Subject Self-Evaluation Form

The following symptoms are sometimes associated with driving simulators. First, please rate your experience of these symptoms as you were driving the simulator, and then rate any symptoms that you may be experiencing now. Indicate your choice by circling the number that most closely represents your experience of the symptom listed to the left. If you experienced any of these symptoms before entering the simulator please inform the experimenter.

0----------1---------2----------3----------4----------5----------6

None — Mild — Extreme

Symptom	Please Rate How You <u>Felt While Driving</u>	Please Rate How <u>How You Feel Now</u>
1. Drowsiness	0 1 2 3 4 5 6	0 1 2 3 4 5 6
2. Difficulty Focusing	0 1 2 3 4 5 6	0 1 2 3 4 5 6
3. Sweating	0 1 2 3 4 5 6	0 1 2 3 4 5 6
4. Confusion	0 1 2 3 4 5 6	0 1 2 3 4 5 6
5. Appetite	0 1 2 3 4 5 6	0 1 2 3 4 5 6
6. Blurred Vision	0 1 2 3 4 5 6	0 1 2 3 4 5 6
7. Eye Strain	0 1 2 3 4 5 6	0 1 2 3 4 5 6
8. Fatigue	0 1 2 3 4 5 6	0 1 2 3 4 5 6
9. Headache	0 1 2 3 4 5 6	0 1 2 3 4 5 6
10. Faintness	0 1 2 3 4 5 6	0 1 2 3 4 5 6
11. Nausea	0 1 2 3 4 5 6	0 1 2 3 4 5 6
12. Salivation	0 1 2 3 4 5 6	0 1 2 3 4 5 6

13. Boredom	0 1 2 3 4 5 6	0 1 2 3 4 5 6
14. Visual Flashbacks	0 1 2 3 4 5 6	0 1 2 3 4 5 6
15. Yawning	0 1 2 3 4 5 6	0 1 2 3 4 5 6
16. Burping	0 1 2 3 4 5 6	0 1 2 3 4 5 6
17. Dizziness	0 1 2 3 4 5 6	0 1 2 3 4 5 6
18. Breathing Difficulty	0 1 2 3 4 5 6	0 1 2 3 4 5 6
19. Mental Depression	0 1 2 3 4 5 6	0 1 2 3 4 5 6
20. Difficulty Concentrating	0 1 2 3 4 5 6	0 1 2 3 4 5 6
21. Overall Discomfort	0 1 2 3 4 5 6	0 1 2 3 4 5 6

Source: Adapted from Simulator Sickness Questionnaire (Kennedy et al., 1993).

GLOSSARY/ACRONYMS

Abbreviations

BTW	Behind-the-Wheel
CDL	Commercial Drivers License—State-administered written knowledge and driving skills test
CMV	Commercial Motor Vehicle
FAA	Federal Aviation Administration
FERT	Final Examination Road Test—Maneuvers executed to criteria demonstrating proficiency development in driving skills for the Safe Operating Practices portion of the PTDI Tractor-Trailer Driver Curriculum
FHWA	Federal Highway Administration
GVWR	Gross Vehicle Weight Rating
HGV	Heavy Goods Vehicle
ITS	Intelligent Transportation System
NADS	National Advanced Driving Simulator
NASA	National Aeronautics and Space Administration
NHTSA	National Highway Traffic Safety Administration
OMC	Office of Motor Carriers
OMCHS	Office of Motor Carrier and Highway Safety
PSRT	Pre-Street Range Test—Maneuvers executed to criteria demonstrating proficiency development in driving skills for the Basic Operation portion of the PTDI Tractor-Trailer Driver Curriculum
PTDI	Professional Truck Drivers Institute

PTDIA	Professional Truck Drivers Institute of America
TRB	Transportation Research Board
TOT	Transfer of Training—Research design with variations used to determine whether (and how much) skill acquisition during training transfers to the actual work environment

Terms

Convergent Validity	Two instruments measuring the same underlying construct should be correlated in the same direction (e.g., a high positive correlation between the simulation-based and truck-based in-course tests)
Predictive Validity	The degree of successful prediction of a criterion with the relationship between the variables under consideration being linear (e.g., how well performance on the FERT predicts *future* performance, CDL)

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*U.S. Government Printing Office: 1999 — 453-174

PUBLICATION NO. FHWA-MC-99-060
HMCS / 6-99 (1M)E